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AFRPL-TR-70-129

22

SEAL DESIGN MODIFICATION FOR AFRPL STAINLESS STEEL THREADED CONNECTORS

J. V. Baum, N. D. Ghadiali, and T. M. Trainer

BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories

TECHNICAL REPORT NO. AFRPL-TR-70-129

December 1970

Air Force Rocket Propulsion Laboratory
Air Force Systems Command
Edwards, California

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SEAL DESIGN MODIFICATION FOR AFRPL STAINLESS STEEL THREADED CONNECTORS

by

J. V. Baum, N. D. Ghadiali, and T. M. Trainer

FOREWORD

This report summarizes research conducted under Exhibit A-1 of USAF Contract No. F04611-69-C-0028 from August, 1969, to September, 1970. The research was performed by the Columbus Laboratories of Battelle Memorial Institute under the auspices of the Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, with Capt. F. M. Cassidy serving as technical manager. The principal investigators were N. D. Ghadiali, Research Engineer; J. V. Baum, Associate Fellow; and T. M. Trainer, Project Manager.

This technical documentary report has been reviewed and is approved:

Francis M. Cassidy
Captain, USAF
Project Engineer

ABSTRACT

An analysis of excessive connector helium leakage indicated that the radial sealing forces in the 1/2-, 3/4-, and 1-inch AFRPL stainless steel threaded connectors were too low to overcome manufacturing variations in the metal-plated seals. A program was undertaken to investigate three candidate materials for increasing the radial sealing forces in these three connector sizes, and to reassess the adequacy of the specification by which the seals were plated, i.e., MIL-P-27418 (USAF), Military Specification, Plating, Soft Nickel. Selected material properties, including yield strength and corrosion resistance, were investigated for cold-worked Type 304 stainless steel, Armco 21-6-9, and iron-base superalloy 19-9 DL. Preliminary tests were conducted for seal designs for each material, and verification tests were conducted for seal designs for Type 304 and Armco 21-6-9 stainless steel. Plating companies were contacted concerning the adequacy of MIL-P-27418 (USAF). It was concluded that the plating specification is satisfactory if the inspection is done with a 5-power glass. It was also concluded that modified seal designs utilizing cold-worked Type 304 stainless steel will achieve the desired performance requirements in the 1/2-, 3/4-, and 1-inch connectors and that the same seal designs utilizing annealed Armco 21-6-9 will probably achieve the desired performance requirements. It was recommended that the necessary changes be incorporated in the plating and connector specifications.

TABLE OF CONTENTS

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TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

SEAL DESIGN MODIFICATION FOR AFRPL STAINLESS STEEL THREADED CONNECTORS

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INTRODUCTION

In April, 1962, the Air Force Rocket Propulsion Laboratory began the development of a family of separable fluid connectors for rocket propulsion systems. Threaded and flanged connectors, called AFRPL connectors, have been developed incorporating a unique "Bobbin" metallic seal. The prior work has been reported in the following Technical Documentary Reports: RTD-TDR-63-1115, December 1963 (AD 426290); AFRPL-TR-65-162, November 1965 (AD 474789); AFRPL-TR-67-191, July 1967 (AD 817843); and AFRPL-TR-69-97, July 1969 (AD 857062).

The last report describes work conducted under Contract AF 04(611)-11204. Phase III of that contract was established to provide engineering support during the introduction of AFRPL threaded connectors to industrial and government agencies. During the introduction period, several 3/4-inch, 4000-psi stainless steel threaded connectors exhibited excessive leakage when installed at the Air Force Rocket Propulsion Laboratory. As described in AFRPL-TR-69-97, an examination of this problem showed that the radial sealing forces in the 1/2-, 3/4-, and 1-inch, 4000-psi threaded connectors were insufficient to overcome manufacturing variations in the seals. Subsequently, Exhibit A-1 was established under Contract No. F04611-69-C-0028 to modify the seal designs for the 1/2-, 3/4-, and 1-inch, 4000-psi AFRPL stainless steel connectors to provide increased radial sealing forces. This report describes the results of this additional effort.

PROGRAM ACTIVITIES

The program activities are described in four report sections. The first section summarizes the background information related to the problem of insufficient radial sealing forces. The second section describes the investigation of materials for use in the Bobbin seals to achieve higher radial sealing forces. The third section reviews the results of preliminary tests conducted with seals made from each of three candidate materials, while the fourth section describes the tests made to verify the performance of the selected seal designs.

Background Information

Four types of background information are pertinent to this report. The first concerns the development of 4000-psi stainless steel threaded connectors. The second is related to the excessive leakage caused by insufficient radial sealing forces in the stainless steel connectors. The third is concerned with the work done on the leakage problem

under the previous program (Contract AF 04 [611]-11204), while the fourth concerns a preliminary investigation of higher strength seal materials under that program.

Connector Development

The primary objective of the first program, Contract AF 04(611)-8176, was to design and evaluate lightweight mechanical connectors that could successfully seal helium to 2 x 10^{-7} atm cc/sec in missile-system environments. As a result of this program, connector design criteria were established, a unique Bobbin seal was conceived, and a threaded connector incorporating the Bobbin seal, for tubing sizes up to 1 inch, was designed and its feasibility demonstrated. This work is described in RTD-TDR-63-1115.

A subsequent program, Contract AF 04(611)-9578, was initiated to design families of threaded-type tube connectors and to demonstrate their ability to meet the extreme requirements of missile fluid systems. Elbows, tees, crosses, and unions made from Type 347 stainless steel, René 41, and 6061-T6 aluminum were designed for standard tubing sizes ranging from 1/8 to 1 inch, and limited qualification tests were performed with selected connector configurations for 3/8-and 3/4-inch tubing systems. Preliminary MS standards and specifications were prepared for selected sizes of 4000-psi stainless steel connectors and for 1000- and 750-psi aluminum connectors. This effort is described in AFRPL-TR-65-162.

Two concurrent efforts were then initiated. In one effort, the Air Force Rocket Propulsion Laboratory reviewed the preliminary standards and specifications, purchased a number of 4000-psi stainless steel connectors, conducted qualification tests with many of the connectors, provided connectors to various facilities for evaluation, and published MS standards and specifications. (Copies of the MS standards for 4000-psi stainless steel connectors are included as Appendix I of this report.) The results of the experimental work at the Rocket Propulsion Laboratory are summarized in Technical Report No. AFRPL-TR-69-98, entitled "Tube Connector Development", by Lt. A. B. Spencer, dated July 1969.

Concurrently with the work at the Rocket Propulsion Laboratory, a three-phase program was conducted by Battelle-Columbus under Contract AF 04(611)-11204. Under Phase I, which is described in AFRPL-TR-97-191, a process was selected for achieving a softer sealing surface for 6061-T6 aluminum seals. Under Phase II, effort was directed toward the development of flight-weight stainless steel and aluminum flanged-type separable connectors utilizing the Bobbin seal for tubing diameters from 1 through 16 inches. Phase III included support for the Rocket Propulsion Laboratory during the introduction of stainless steel threaded connectors to industry, and the investigation of mutually selected aspects of threaded connectors. The effort on Phases II and III is described in AFRPL-TR-69-97.

Excessive Leakage With Stainless Steel Seals

Beginning in 1967, three events occurred which showed the need for improved initial sealing in the 3/4- and 1-inch, 4000-psi stainless steel AFRPL threaded connectors.

In the first event, twenty 3/4-inch connectors were installed in a liquid-hydrogen system at the Rocket Propulsion Laboratory. This installation was part of the effort by

the Rocket Propulsion Laboratory to obtain information concerning the use of AFRPL threaded connectors by various agencies and laboratories. Five of the 20 connectors leaked badly. Because leakage of this extent had not been encountered in the developmental testing of the connector, three of the connectors and the seals from the other two connectors were forwarded to Battelle-Columbus for analysis.

In the second event, personnel at the Rocket Propulsion Laboratory decided to conduct misalignment tests with threaded connectors. Although a misalignment test had not been part of the development tests of the threaded connectors, the test had proved to be beneficial in evaluating flanged connectors, and similar tests were conducted with 3/4-inch, 4000-psi stainless steel threaded connectors at the Rocket Propulsion Laboratory. It was found that satisfactory initial sealing was often not achieved in these misalignment tests.

In the third event, near the end of Contract AF 04(611)-11204, satisfactory sealing could not be maintained during the thermal-gradient testing of the 8-inch, 1500-psi stainless steel flanged connector. Although the seals used in this connector were much larger than the seals used in the threaded connectors, the radial sealing forces for the flanged and threaded connector seals were similar.

Leakage Investigation Under Contract AF 04(611)-11204

During the latter months of Contract AF 04(611)-11204, considerable work was done in relation to the excessive leakage that had been encountered with stainless steel threaded and flanged connectors. Seals were inspected before assembly to note the type of imperfections on the sealing surfaces; seals were assembled with different sealing pressures (by changing the strength of the seals); leakage tests were conducted; and seals were inspected after disassembly to note the ability of the different sealing forces to overcome the different types of sealing-surface imperfections.

As a result of this work, it was concluded that most of the leakage for the threaded and the flanged stainless steel connectors occurred because the sealing forces were insufficient to overcome manufacturing variations in the sealing surfaces of the seals.

For 4000-psi stainless steel threaded connectors, it was concluded that the seals required a minimum sealing pressure of about 6 times and an average sealing pressure of about 7-1/2 times the yield strength of the soft nickel used to plate the seals. These pressures were required to overcome the plating pits, nodules, and ripples that seem to be associated with the plating state of the art. It was also concluded that a sealing-surface width of 0.020 inch was desirable to seal around edge nicks and small plating imperfections. The yield strength of soft nickel is approximately 10,000 psi. Therefore, the seals had to achieve radial sealing forces ranging from a minimum of about 1200 lb/in. of seal circumference to an average of about 1500 lb/in. of seal circumference.

Calculations and tests made at the Rocket Propulsion Laboratory and at Battelle-Columbus showed that seals made according to the MS standard (MS 27855 – see Appendix I) and the plating specification, MIL-P-27418(USAF), were satisfactory for 1/8-, 1/4-, and 3/8-inch seals. (A copy of the plating specification is included as Appendix II of this report.) For 1/2-inch seals, the radial sealing force was somewhat low, and for 3/4- and 1-inch seals the radial sealing forces were significantly low.

Seal Material Investigation Under Contract AF 04(611)-11204

Because extensive effort had been expended on tests with the existing connector dimensions and on preparation of the existing MS standards, it was highly desirable to achieve increased radial sealing forces with as few dimensional changes as possible. A preliminary study under Contract AF 04(611)-11204 showed that three materials were promising for achieving higher radial sealing forces in the 1/2-, 3/4-, and 1-inch seals: (1) cold-worked Type 304 stainless steel, (2) 19-9 DL stainless steel, and (3) a relatively new stainless steel by Armco called 21-6-9.

Type 304 stainless steel (hereinafter referred to as 304) is capable of being cold worked to very high yield strengths. In fact, the major problem with the material appeared to be the wide range in yield strengths for cold-worked bars. Although a 100 percent increase in tensile yield strength, as compared to the annealed material, was desirable, tests showed that a 200 percent increase in yield strength would damage the plain flange of the 1-inch connector. Yield-strength increases up to 300 percent are possible in cold-worked 304. Since the maximum yield strength of cold-worked bars is not normally specified nor controlled, the problem of limiting the maximum yield strength of the material had to be determined.

The second candidate, 19-9 DL, is an iron-base superalloy. It has an ideal yield strength (70,000 to 85,000 psi), and appeared to be readily available. Although an examination of the composition of 19-9 DL indicated that it would be sufficiently corrosion resistant, few data existed for its exposure to rocket propulsion fluids. The lack of corrosion data appeared to be the biggest problem with 19-9 DL.

The third candidate, 21-6-9, is an austenitic stainless steel. Although its corrosion resistance to rocket propulsion fluids was not known, its composition indicated that it would be similar to Type 316 stainless steel. The biggest problem with 21-6-9 appeared to be the fact that the annealed tensile yield strength was not very high (50,000 to 60,000 psi). While this was some improvement over annealed austenitic stainless steel, it was not as much as desired. Another problem was the fact that there was only one supplier, and 21-6-9 was not readily available in the bar sizes of interest.

Thus, at the conclusion of Contract No. AF 04(611)-11204, there were aspects about each candidate seal material that needed further investigation. It was recommended that the properties of the candidate materials be studied further, and that seals of each of the materials be designed and tested. It was also recommended that this information be used to select the optimum seal design, and that qualification tests be conducted for the selected design.

Investigation of Seal Materials

The investigation of seal materials under Contract No. F04611-69-C-0028 consisted of three types of efforts: (1) further investigation of selected properties of the candidate seal materials, (2) investigation of the corrosion resistance of the candidate seal materials, and (3) reassessment of the nickel-plating quality as required in MIL-P-27418(USAF).

Selected Properties of Candidate Seal Materials

Table I shows the properties of the candidate seal materials which are important to the successful performance of the threaded connectors. The properties for the connector material, Type 347 stainless steel, are also shown. No problems were envisioned for any of the candidate seal materials from the standpoints of coefficient of thermal expansion, machinability, or cost. Possible problems of corrosion compatibility with rocket fluids existed for two of the seal materials, and the results of an experimental investigation of their corrosion resistance are described in the next report section. Other problems existed from the standpoints of yield strength and material availability. These are discussed for each candidate seal material.

TABLE I. SELECTED PROPERTIES OF CONNECTOR MATERIAL AND CANDIDATE SEAL MATERIALS

Selected Material Property	Connector Material, Annealed Austenitic Stainless Steel, Type 347	Candidate Seal Materials: Cold-Worked Austenitic Stainless Steel, Type 304	Candidate Seal Materials: Annealed Austenitic Stainless Steel, Armco 21-6-9	Candidate Seal Materials: Iron-Base Superalloy, 19-9 DL
Tensile Yield Strength at 70 F, ksi	35 - 50	50 - 120	50 - 65	70 - 100
Coefficient of Thermal Expansion, 10^{-6} in./in./F	9.3	9.6	9.3	10
Machining Index	50	40	45	40
Compatibility With Rocket Fluid Systems	Very good	Good	Unknown	Unknown
Approximate Cost, $/lb	0.75	0.50	0.75	1.00
Available Forms	Sheet, plate, bar	Sheet, plate, bar, tubing	Sheet, bar, wire	Sheet, bar, tubing

Type 304 Stainless Steel. On the basis of preliminary work done under Contract AF 04(611)-11204, it was thought that the yield strength of most cold-rolled 304 bar ranged from about 70,000 psi to about 100,000 psi. With this range, it appeared that the same dimensions could be used for seals made of 304 as for seals made of 19-9 DL.

However, more extensive contacts with manufacturers and suppliers under Contract No. F04611-69-C-0028 showed that the most common cold-worked bar stock available is annealed and cold rolled. The yield strength of the material in a given bar depends on the yield strength of the original billet and on the amount of cold-work reduction used to get the finished bar size. For the 1-inch bars that are required for the 3/4-inch seals, and for the 1-1/4-inch bars that are required for the 1-inch seals, the yield strength of stock normally available on an odd-lot basis from a supply house ranges from about 50,000 psi to about 100,000 psi, with the majority of the stock ranging from about 55,000 psi to about 85,000 psi.

Unfortunately, a 30,000-psi range of yield strength is too great for a good seal design. If the seal were designed for a minimum radial sealing force with 55,000-psi stock, the use of 85,000-psi stock would damage the 1-inch plain flange. On the other hand, if the seal were designed for a maximum radial sealing force with 85,000-psi stock, the radial force with 55,000-psi stock would be too low.

The decision was made to select 50,000 and 70,000 psi as the minimum and maximum allowable tensile yield strengths, respectively, for seals made of 304. This decision was based on the fact that it was estimated early in the program that the effective compressive yield strength of cold-worked 304 was sufficiently high that the dimensions in MS 27855 could be used for 304 seals made of materials with these tensile yield strengths.

It was realized that the selection of yield-strength limits of 50,000 and 70,000 psi might require a purchasing agent to contact four or five suppliers to obtain satisfactory stock. However, this was judged to be acceptable. In the unlikely event that satisfactory stock could not be obtained at a given time, two courses of action could be taken. First, a larger size bar could be purchased with a resulting increase in cost for material and machining. This was thought to be acceptable for small quantities of seals. For larger seal quantities, 500-pound minimum orders could be placed for the required yield-strength range. There would normally be a time delay on such orders of 60 to 120 days, depending on the production plans at the mills. It is common practice to add such orders to a larger order so the material can be included in a future billet. When the yield strength of the billet has been determined, it is possible to estimate the amount of cold work needed to obtain an acceptable bar size and yield strength for the partial order.

Armco 21-6-9 Stainless Steel. During the work under Contract AF 04(611)-11204, it was thought that the lower yield-strength range of 21-6-9 as compared to that of 19-9 DL (see Table I) posed a problem in designing 3/4- and 1-inch seals with sufficient radial sealing forces. Work under Contract No. F04611-69-C-0028 showed that satisfactory strength could be achieved in these seals if material was added to the seal disks as well as to the seal tang.

Further discussion with Armco did show, however, that very little 21-6-9 bar stock was being made. Apparently the primary use of 21-6-9 was in sheet and tubing forms. Armco personnel said that minimum orders of 500 pounds would be filled within a few weeks, and the Technical Manager decided that this situation would not be prohibitive. On the other hand, it was apparent that an alternative seal material would be highly desirable.

Iron-Base Superalloy 19-9 DL. During the work under Contract AF 04(611)-11204, the only possible problem envisioned for 19-9 DL was one of insufficient corrosion resistance in rocket fluid systems. The material was originally developed for use in jet engines and no known data were available concerning its performance in rocket fluids.

However, as a result of more detailed investigations under Contract No. F04611-69-C-0028, a problem of availability developed with 19-9 DL. It was found that newer materials, such as 17-4 PH, were sufficiently more desirable to users of high-strength stainless steel that supply houses had decided to stop stocking 19-9 DL. It was possible to obtain enough material to make seals for the program, but it was estimated that within a year all 19-9 DL material would have to be ordered directly from a mill. While the material would not be impossible to obtain, significant time and cost penalties would be incurred for small-lot orders.

Corrosion Resistance of the Candidate Seal Materials

Because of the unknown corrosion resistance of 21-6-9 and 19-9 DL to rocket fluids, a program was conducted by the Liquid Rocket Division of the Air Force Rocket Propulsion Laboratory to compare the corrosion resistance of these materials with the corrosion resistance of 304. Data from this investigation were to be used in the selection of a material for improved Bobbin seals under Contract F04611-69-C-0028.

Appendix III contains a copy of a Technical Memorandum, AFRPL-TM-70-8, that summarizes the preliminary results of the corrosion investigation. It was decided that two fluids, nitrogen tetroxide (N_2O_4) and chlorine trifluoride (ClF_3), were representative of the fluids used in rocket fluid systems. It was known that the corrosion resistance of 304 was satisfactory, and it was decided that the exposure of all three candidate seal materials, 304, 21-6-9, and 19-9 DL, under identical conditions would give data concerning the relative performance of the two "new" materials. Because the Bobbin seals are nickel plated, the effect of plating on corrosion resistance was investigated by exposing plated and unplated specimens.

To quote from the Results and Discussions section of AFRPL-TM-70-8:

> "It appears from data gathered in the past three months, that the three types of stainless steels in the unplated condition are compatible with N_2O_4 under the test conditions described. The nickel-plated coupons, however, are considered incompatible due to the formation of the lime-green nickel nitrate corrosion product. . . . It appears so far that the three candidate stainless steels are compatible with ClF_3 in both the plated and the unplated conditions."

Reassessment of MIL-P-27418 (USAF), Military Specification, Plating, Soft Nickel

Because the sealing problems being investigated under Contract FO4611-69-C-0028 were concerned with the forces needed to overcome imperfections in the nickel plating, part of the effort was directed toward a reassessment of the specification by which stainless steel Bobbin seals are plated. This specification, MIL-P-27418 (USAF), appears in Appendix II.

Letters were sent to 49 plating companies that were thought to be candidates for bidding to the requirements of MIL-P-27418 (USAF). A copy of the specification was enclosed with each letter, as was a nickel-plated Bobbin seal. Each company was asked to comment on the adequacy of the specification, on their ability to plate according to the specification, and on their willingness to bid in response to a request for quotation. The replies were as follows:

(a)	No experience with nickel sulfamate plating	21
(b)	Cannot plate to MIL-P-27418	3
(c)	Plate plastic parts only	1
(d)	Can plate to specification; will quote	4
(e)	Can plate to specification; will not quote	5

(f) Do not plate on contract basis 4

(g) Plate industrial components only 1

(h) No reply 10

On the basis of the investigation, it was concluded that the specification is adequate. The candidate seal materials are platable and the desired hardness, thickness, and adhesion can be obtained. (It was recommended in AFRPL-TR-69-97 that the inspection required in the specification be conducted with a 5-power glass.) It is probable that some problems might be encountered the first time an order is placed, as familiarity with handling of the seals is being gained.

The five companies (including the company that plated the experimental seals) that can be asked to quote on a plating purchase order are:

Allied Metal Finishing
4004 East Monument Street
Baltimore, Maryland 21205

Cambridge Plating Company, Inc.
39 Hittenger Street
Belmont, Massachusetts 02178

Lancaster Electro Plating Company
Lancaster, Ohio

Orbit Electric Company, Inc.
Montana Road
Phillipsburg, New Jersey 08865

Precision Plating Company
6045 North Keystone Avenue
Chicago, Illinois 60646

Preliminary Test Program

Consideration of the differences of the candidate seal materials led to the selection of certain connector performance requirements as being the most critical for each seal material. These critical performance requirements were used to establish preliminary tests which could be used to assist in the selection of the best seal material.

A summary of these preliminary tests, which is shown in Table II, was included in the work statement. The tests were established on the basis that 21-6-9 might be selected for all three seal sizes, while 304 and 19-9 DL, with their high yields strengths, were candidates only for the 3/4- and 1-inch seals.

The preliminary test program consisted of three parts: (1) the design and fabrication of the test seals, (2) the conduct of the preliminary tests, and (3) the selection of the best seal material and design for verification testing.

TABLE II. PRELIMINARY-TEST SUMMARY

Test:	Axial Load			Thermal Gradient			Vibration			Misalignment		
Seal Size, in:	1/2	3/4	1	1/2	3/4	1	1/2	3/4	1	1/2	3/4	1
Material												
19-9 DL												
Min Yield		X	X			X					X	X
Max Yield		X	X									
21-6-9												
Min Yield	X	X	X			X			X			
Max Yield	X	X	X							X		
304												
Min Yield		X	X			X			X			
Max Yield		X	X								X	X

Seal Design and Fabrication

The design and fabrication aspects for each of the candidate seal materials are discussed.

Iron-Base Superalloy 19-9 DL. One of the most attractive features about 19-9 DL was the fact that the minimum tensile yield strength required by the military specification on the material was 70,000 psi. This value gave a calculated radial sealing force of about 1260 and 1220 lb/in. of seal circumference for the 3/4- and 1-inch seals, respectively, when used with the dimensions in MS27855. This compared very favorably with the desired minimum of about 1200 lb/in. of seal circumference. This indicated that no change in the specification dimensions would be required for 19-9 DL.

On the basis of telephone calls to supply houses concerning available stock (of which there was very little), a practical maximum yield strength of 90,000 psi was selected. Using the dimensions in MS27855, the radial sealing forces for the 3/4- and 1-inch seals with 90,000-psi material were calculated to be 1620 and 1570 lb/in. of seal circumference, respectively. The value for the 1-inch seal was well under the 2300 lb/in. of seal circumference established under Contract AF 04(611)-11204 as the maximum radial sealing force possible for the 1-inch plain flange.

It was known from work under Contract AF 04(611)-11204 that the effective compressive yield strength was 50,000 psi for austenitic stainless steel with a certified tensile yield strength of 35,000 psi. This was caused by the large amount of strain created in the seal during seal seating and deformation. Stress-strain curves for 19-9 DL were studied to obtain an estimate of the effective compressive yield strength for this material. It was estimated that the tensile yield strengths would be increased about 7000 psi. Table III shows the radial sealing forces calculated for the 3/4- and 1-inch seals using the estimated minimum and maximum effective compressive yield strengths.

TABLE III. NOMINAL RADIAL SEALING FORCES FOR 19-9 DL SEALS CALCULATED USING DIMENSIONS IN MS27855 AND ESTIMATED EFFECTIVE COMPRESSIVE YIELD STRENGTHS

Tubing Size, in.	A Tensile Yield Strength, 0.2% Offset, ksi	B Estimated Nominal Compressive Yield Strength, ksi	Calculated Radial Sealing Force Using B, lb/in. of seal circumference
3/4	70.0	77.0	1382
3/4	90.0	97.0	1742
1	70.0	77.0	1343
1	90.0	97.0	1692

It was not possible to buy bar stock for the 19-9 DL seals with tensile yield strengths of 70,000 psi and 90,000 psi. To simulate these materials, the certified tensile yield strengths for the available materials were used to estimate their effective compressive yield strengths. The ratios of the estimated actual compressive yield strengths to the nominal compressive yield strengths were then used in the radial-sealing-force calculation to determine the amount of material that should be added or subtracted from the seal inside diameters. Table IV shows the inside diameters for the 19-9 DL seals used in the preliminary tests.

TABLE IV. MODIFIED INSIDE DIAMETERS OF 19-9 DL SEALS USED IN PRELIMINARY TESTS

Tubing Size, in.	A Estimated Nominal Compressive Yield Strength, ksi	B Certified Tensile Yield Strength of Purchased Matl., ksi	C Estimated Actual Compressive Yield Strength, ksi	Nominal Seal ID, in.	Modified Seal ID to Simulate A, in.
3/4	77.0	76.0	83.0	0.572	0.588
3/4	97.0	89.0	96.0	0.572	0.569
1	77.0	76.0	83.0	0.744	0.762
1	97.0	84.0	91.0	0.744	0.730

Armco 21-6-9 Stainless Steel. The poor availability of 21-6-9 was emphasized by the fact that only one bar of material could be obtained during the experimental program. This was the case despite repeated telephone calls to the supplier and the mill, and despite a willingness to accept oversize stock in the interest of obtaining bars with different yield strengths.

The bar that was obtained had a certified tensile yield strength of 60,000 psi. The bulletin from Armco on 21-6-9 lists 57,000 as the average tensile yield for 1-inch bars. Discussions with Armco personnel led to the selection of 50,000 psi and 70,000 psi as the minimum and maximum tensile yield strengths to be expected in normal production lots of annealed 21-6-9 for bar sizes from 3/4-inch (for the 1/2-inch seals) to 1-1/4-inch (for the 1-inch seals).

As described in AFRPL-TR-69-97, considerable work had been done under Contract No. AF 04(611)-11204 with 21-6-9 seals made from a bar of material having a certified tensile yield strength of 57,500 psi. On the basis of measured radial sealing forces for the seals, that material exhibited an effective compressive yield strength of

about 65,000 psi. Combining this information with a study of stress-strain curves of similar materials, it was estimated that the tensile yield strengths of 21-6-9 should be increased about 5000 psi to obtain the effective compressive yield strength.

Table V gives the radial sealing forces calculated for 1/2-, 3/4-, and 1-inch seals made to the dimensions of MS27855 using the minimum and maximum estimated effective compressive yield strengths. It can be seen in Column C that the radial sealing forces with the minimum-yield-strength material were less than the desired minimum of 1200 lb/in. of seal circumference for all seal sizes.

TABLE V. NOMINAL RADIAL SEALING FORCES FOR 21-6-9 SEALS USING SPECIFICATION DIMENSIONS AND MODIFIED SPECIFICATION DIMENSIONS

	A	B	C	D
Tubing Size, in.	Tensile Yield Strength 0.2% Offset, ksi	Estimated Effective Compressive Yield Strength, ksi	Calculated Radial Sealing Force Using B and Spec Dimensions, lb/in. of seal circumference	Calculated Radial Sealing Force Using B and Modified Spec Dimensions, lb/in. of seal circumference
1/2	50.0	55.0	1102	1246
1/2	70.0	75.0	1504	1698
3/4	50.0	55.0	986	1256
3/4	70.0	75.0	1348	1712
1	50.0	55.0	965	1220
1	70.0	75.0	1316	1665

To increase the amount of material in the seals while minimizing the effect on the dimensions of MS27855, it was decided that only the thickness of the seal disks and the length of the seal tang would be increased. Table VI shows the original and modified values for these dimensions. Column D in Table V shows the radial sealing forces calculated using the modified dimensions and the estimated effective compressive yield strength.

TABLE VI. MODIFICATION OF SEAL DIMENSIONS IN MS27855 FOR 21-6-9 SEALS

	Tang Length, in.	Disk Thickness, in.
1/2-Inch Seal		
Specification dimension	0.150	0.027
Modified dimension	0.160	0.035
3/4-Inch Seal		
Specification dimension	0.150	0.027
Modified dimension	0.180	0.035
1-Inch Seal		
Specification dimension	0.150	0.027
Modified dimension	0.180	0.040

As with the 19-9 DL seals, it was necessary to modify the inside diameters of the test seals so the minimum-compressive-yield-strength material (55,000 psi) and the maximum-compressive-yield-strength material (75,000 psi) could be simulated with the available material which had an estimated compressive yield strength of 65,000 psi. Table VII shows the modified inside diameters of the 21-6-9 seals used in the preliminary tests.

TABLE VII. MODIFIED INSIDE DIAMETERS OF 21-6-9 SEALS USED IN PRELIMINARY TESTS

Tubing Size, in.	A Estimated Nominal Compressive Yield Strength, ksi	B Estimated Actual Compressive Yield Strength, ksi	Nominal Seal ID, in.	Modified Seal ID to Simulate A, in.
1/2	55.0	65.0	0.382	0.406
1/2	75.0	65.0	0.382	0.358
3/4	55.0	65.0	0.572	0.602
3/4	75.0	65.0	0.572	0.542
1	55.0	65.0	0.744	0.781[a]
1	75.0	65.0	0.744	0.707[a]

(a) The load test seals were inadvertently made without increased tang and disk thickness. The load-test results were valid, however, as an experimental check on the calculated radial sealing forces for seals made to the dimensions in MS27855- see Column C in Table V.

Type 304 Stainless Steel. As described previously, minimum and maximum tensile-yield-strength values of 50,000 and 70,000 psi were selected for annealed and cold-rolled 304 bars. An examination of the stress-strain curves for 304 materials showed that a considerable increase in yield strength occurred for the amount of strain estimated to occur in the Bobbin seals of the threaded connectors. On the basis of this information, it was estimated that the effective compressive yield strength of the material in the Bobbin seals would be from 23,000 to 25,000 psi higher than the tensile yield strength. As shown in Table VIII, it was estimated that seals made to the dimensions given in MS27855 would provide adequate radial sealing forces.

TABLE VIII. NOMINAL RADIAL SEALING FORCES FOR 304 SEALS USING DIMENSIONS IN MS27855 AND ESTIMATED EFFECTIVE COMPRESSIVE YIELD STRENGTHS

Tubing Size, in.	A Tensile Yield Strength, 0.2% Offset, ksi	B Estimated Effective Compressive Yield Strength, ksi	Calculated Radial Sealing Force Using B, lb/in. of seal circumference
3/4	50.0	75.0	1348
3/4	70.0	93.0	1672
1	50.0	75.0	1315
1	70.0	93.0	1634

Two bars of cold-rolled 304 were selected for the preliminary tests. One bar had a certified tensile yield strength of 54,000 psi, while the other bar had a certified tensile yield strength of 77,500 psi. Table IX shows the effective compressive yield strengths estimated for these materials and the modified inside diameters selected to simulate the nominal minimum and maximum effective compressive yield strengths.

TABLE IX. MODIFIED INSIDE DIAMETERS OF 304 SEALS USED IN PRELIMINARY TESTS

Tubing Size, in.	A: Estimated Nominal Compressive Yield Strength, ksi	B: Certified Tensile Yield Strength of Purchased Material, ksi	C: Estimated Actual Compressive Yield Strength, ksi	Nominal Seal ID, in.	Modified Seal ID to Simulate A, in.
3/4	75.0	54.0	79.0	0.572	0.581
3/4	93.0	77.5	100.0	0.572	0.585
1	75.0	54.0	79.0	0.744	0.756
1	93.0	77.5	100.0	0.744	0.760

Preliminary Test Results

As shown in Table II, the preliminary experimental evaluation of the three candidate seal designs consisted of four types of tests: (1) load tests, (2) thermal gradient tests, (3) vibration tests, and (4) misalignment tests. The procedures and results for each type of test are discussed briefly.

Load Tests. Seals of each design were load tested to determine whether the desired radial sealing forces were obtained. Each test was conducted in a Universal testing machine. Each seal was seated with one disk in a plain flange and one disk in a strain-gaged load ring. As each seal was seated, the axial force needed to seat the seal was measured by the Universal testing machine, and the radial sealing force created by the seal was calculated from the strain measured in the strain-gaged load ring. (The load ring was simply a ring of high-strength steel placed around one seal disk. As the seal disk pressed against the inside diameter of the load ring as a result of the seal seating action, strain gages on the outside diameter of the load ring measured the strain in the load ring.)

Table X shows the results of the tests, which were made on seals of the designs listed in Table II Preliminary-Test Summary. The results for the 19-9 DL seals showed that the effective compressive yield strength of the material was somewhat higher than that estimated from the literature. In fact, since the strength of the 1-inch plain flange is limited to about 2300 lb/in. of seal circumference (as determined under Contract AF 04[611]-11204), the tests showed that 90,000 psi is the maximum tensile yield strength that can be accepted for seals machined from 19-9 DL to the dimensions of MS27855.

Overall evaluation of the 21-6-9 load-test results indicated that the seal designs were satisfactory. Although the strain-gaged load ring for the 1/2-inch 21-6-9 seals yielded during the preliminary load tests, the measured radial sealing forces for the 3/4- and 1-inch seals were very close to the calculated values and it was judged that the values for the 1/2-inch seals would have been as close. This judgment was strengthened by the similarity of the average maximum axial force per inch of seal circumference required to seat the 1/2- and 3/4-inch seals. For the 1/2- and 3/4-inch seals simulating a tensile yield strength of 50,000 psi, these values were 750 and 870 lb/in. of seal circumference, respectively. For the 1/2- and 3/4-inch seals simulating a tensile yield strength of 70,000 psi these values were 1000 and 1100 lb/in. of seal circumference, respectively.

TABLE X. PRELIMINARY LOAD-TEST RESULTS FOR THE CANDIDATE SEAL DESIGNS

Seal Material	Tubing Size, in.	Simulated Tensile Yield, ksi	Available[a] Axial Assembly Force, lb	Maximum Measured Axial Seating Force, lb	Calculated Maximum Radial Sealing Force, lb/in. of seal circumference	Measured Maximum Radial Sealing Force, lb/in. of seal circumference
19-9 DL	3/4	70.0	5510	2730 2200 2730	1382	1300 1740 1840
19-9 DL	3/4	90.0	5510	2820 2920 3030 2940	1742	1860 2000 2100 2090
19-9 DL	1	70.0	8764	3210 3780 3090	1343	1260 1420 1300
19-9 DL	1	90.0	8764	3540 3820 3660	1392	1610 1920 2010
21-6-9	1/2	50.0	2800	1500 1560 1530	1246	(b)
21-6-9	1/2	70.0	2800	1980 2200 1980	1698	(b)
21-6-9	3/4	50.0	5510	2475 2580 2475	1256	1530 1650 1480
21-6-9	3/4	70.0	5510	3375 3300 3360	1712	1700 1490 1780
21-6-9	1	50.0	8764	2220 2340 2280	965[c]	1410 1010 765
21-6-9	1	70.0	8764	2730 2490 2700	1316[c]	1140 1380 1260
304	3/4	50.0	5510	1650 1670	1348	725 795
304	3/4	70.0	5510	2130 2660	1672	1110 1900
304	1	50.0	8764	2100 2040	1315	1070 770
304	1	70.0	8764	2450 2700	1634	1570 1040

(a) From Table 61, page 177, of AFRPL-TR-69-97.

(b) The load ring yielded, preventing accurate strain-gage readings.

(c) These values are from Column C in Table V, since the 1-inch seals were inadvertently machined to the dimensions in MS 27855.

Because radial sealing forces were shown under Contract AF 04(611)-11204 to be related to axial seal seating forces, it was judged that the radial sealing forces for the 1/2- and 3/4-inch seals were similar.

The load-test results for the 304 seals showed that the effective compressive yield strength of the material was much lower than had been estimated from the literature. Using the measured radial sealing forces, the effective compressive yield strengths were calculated for the test seals. On the basis of these calculations, it was decided that the effective compressive yield strength for cold-rolled 304 was approximately the same as that of 21-6-9. Thus it was concluded that the dimensions for the 21-6-9 seals could be used for the cold-rolled 304 seals.

Thermal-Gradient Tests. As shown in Table II, tests were conducted for 1-inch connectors with minimum-strength seal materials of 19-9 DL, 304, and 21-6-9. Six thermal cycles were conducted on each seal from +200 F to -320 F, using procedures outlined in MIL-F-27417 (USAF). This specification is contained in Appendix IV. The results of these tests showed that any of the seal materials and configurations would be satisfactory since no leakage was measured during the tests.

Vibration Tests. Vibration tests were completed with 1-inch connectors using minimum-strength seals for all three materials. The vibration test on 19-9 DL was in addition to the tests on 21-6-9 and 304 shown in Table II. The tests were conducted at a natural frequency of vibration of approximately 350 cps and at stress levels corresponding to design bending-moment levels of 900 in-lb. Test conditions also included a connector pressure of 4000 psi and a temperature of 200 F. As specified in MIL-F-27417 (USAF), the connector assemblies were vibrated for a minimum of 300,000 cycles. No leaks were measured. Thus, the results indicated that any one of the three materials and seal configurations would be satisfactory with regard to the vibration tests.

Misaligment Tests. As shown in Table II, tests were conducted for 1/2-, 3/4-, and 1-inch connectors under misalignment conditions. For these tests the connectors were subjected to static bending moments of 60 in-lb for the 1/2-inch, 192 in-lb for the 3/4-inch, and 388 in-lb for the 1-inch connector.

The maximum misalignment angles at which connector assemblies could be accomplished under the above bending-moment loads were 2-1/2 degrees for the 1/2-inch connectors, and 1-1/2 degrees for the 3/4- and 1-inch connectors. These misalignment conditions were found to be independent of the seal variations under study. With an internal pressure of 4000-psi helium, no leakage could be detected from any of the connectors using a helium sniffing device and a helium mass spectrometer.

Design Selection

On the basis of the preliminary-development-test results and the preliminary corrosion results, two approaches to seal material selection were feasible. One was to specify seal-material yield strengths of 50,000 to 70,000 psi. The other was to specify material yield strengths of 70,000 psi to 90,000 psi. For the first approach, either 304 in a work-hardened condition or annealed 21-6-9 could be used if the specification seal dimensions were increased. For the second approach, 19-9 DL material could be

used and the seal dimensions in MS27855 would remain unchanged. Because of the anticipated difficulties in obtaining 19-9 DL material, it was mutually agreed with the Technical Manager that the first approach would be selected.

Because the original estimates for the verification testing of the selected design anticipated the selection of only one material, there were not sufficient funds to test 21-6-9 and 304 seals. It was decided that a complete series of tests would be conducted with 304 stainless steel since that was the most readily available material. Some of the verification tests were also conducted with seals made of 21-6-9 to give an increased understanding of the applicability of this material.

Verification Test Program

A verification test program was established to demonstrate that the seal designs selected as a result of the preliminary test program were satisfactory. A summary of the verification tests, which was contained in the work statement, is shown in Table XI. The verification tests included three tests in addition to those contained in the preliminary test schedule. The verification testing will be discussed for each type of seal material.

TABLE XI. VERIFICATION TEST SUMMARY

	Seal Size, in.					
	1/2		3/4		1	
Test	Minimum Yield	Maximum Yield	Minimum Yield	Maximum Yield	Minimum Yield	Maximum Yield
Load test	x	x	x	x	x	x
Thermal gradient	x				x	
Stress-reversal bending			x			
Vibration	x				x	
Pressure impulse	x		x		x	
Repeated assembly				x		
Misalignment	x	x	x	x	x	x

Verification Testing of 304 Stainless Steel Seals

The 304 seals for the verification tests were machined to the same nominal dimensions as the 21-6-9 seals. The basic dimensions are shown in MS27855 of Appendix I, while the modified tang lengths and disk thicknesses are shown in Table VI. As with the seals for the preliminary tests, it was necessary to modify the inside diameters of the seals to simulate the nominal minimum and maximum tensile yield strengths. These ID modifications are shown in Table XII. The seals were nickel plated in accordance with MIL-P-27418 (USAF). Examination of the seals after plating showed the plating to be of good quality.

TABLE XII. MODIFIED INSIDE DIAMETERS OF 304 SEALS USED IN VERIFICATION TESTS

Tubing Size, in.	Nominal Tensile Yield Strength, ksi	Actual Tensile Yield Strength, ksi	Nominal Seal ID, in.	Modified Seal ID, in.
1/2	50.0	54.0	0.382	0.393
1/2	70.0	77.5	0.382	0.397
3/4	50.0	54.0	0.572	0.585
3/4	70.0	77.5	0.572	0.590
1	50.0	54.0	0.744	0.761
1	70.0	77.5	0.744	0.766

Load Tests. Table XIII shows the results of the verification load tests conducted with the 304 seals. The results were judged to be very good. The minimum radial sealing forces measured with the seals simulating the minimum tensile yield strengths were close to the desired minimum radial sealing force of 1200 lb/in. of seal circumference. The maximum radial sealing forces measured with the seals simulating the maximum-tensile-yield-strength material provided a good margin of safety for the maximum radial sealing force that can be sustained by the 1-inch plain flange, i.e., 2300 lb/in. of seal circumference.

TABLE XIII. VERIFICATION LOAD-TEST RESULTS FOR 304 SEALS

Tubing Size, in.	Simulated Tensile Yield, ksi	Available Axial Assembly Force, lb	Maximum Axial Force, lb	Calculated Radial Sealing Force, lb/in. of circumference	Maximum Measured Radial Sealing Force, lb/in. of circumference	Average Radial Sealing Force, lb/in. of circumference
			1680		1620	
1/2	50.0	2800	1650	1240	1550	1620
			1650		1690	
			1840		1750	
1/2	70.0	2800	1920	1698	1840	1830
			1870		1910	
			2220		1150	
3/4	50.0	5510	2240	1256	1720	1480
			2220		1570	
			3080		1760	
3/4	70.0	5510	2570	1712	1210	1720
			2580		2200	
			3420		1360	
1	50.0	8764	3360	1220	1230	1240
			3180		1130	
			4380		1550	
1	70.0	8764	4500	1665	1790	1625
			4320		1540	

Examination of the sealing surfaces of the seals after removal from the plain flanges and load rings showed that the width of the sealing surfaces ranged from about 0.018 to about 0.025 inch. This compared very favorably with a desired width of 0.020 inch.

The sealing surfaces were uniformly shiny and smooth. These are the conditions needed to achieve good initial sealing.

Thermal-Gradient Tests. Thermal-gradient tests were conducted in accordance with MIL-F-27417 (USAF) on minimum-strength seals for 1/2- and 1-inch connectors as listed in Table XI. Two seals of each size were tested. No helium leakage could be detected by the mass spectrometer during six thermal-shock cycles.

Stress-Reversal Bending. Two minimum-strength 3/4-inch seals were tested in stress-reversal bending in accordance with MIL-F-27417 (USAF). No helium leakage could be detected during 300,000 cycles of testing.

Vibration. Vibration tests were conducted in accordance with MIL-F-27417 (USAF) on minimum-strength seals for 1/2- and 1-inch connectors as listed in Table XI. Two seals of each size were tested. No helium leakage could be detected during the tests.

Pressure Impulse. As listed in Tablx XI, pressure-impulse tests were conducted with one minimum-strength seal for 1/2-, 3/4- and 1-inch connectors. The connectors were subjected to pressure impulses of 0 to 6000 psi at the rate of 40 per minute until 300,000 pressure-impulse cycles had been completed. No leakage could be detected from the connectors. Oil was used as the pressurizing medium to achieve sharp pressure impulses.

Repeated Assembly. A repeated-assembly test was conducted with 25 maximum-strength 3/4-inch seals in accordance with MIL-F-27417 (USAF). No helium leakage could be detected during the leakage tests conducted with each fifth seal. In addition, no damage could be detected to the 3/4-inch plain flange that was used for all of the tests.

Misaligment. Misalignment tests were conducted with minimum- and maximum-strength seals for 1/2-, 3/4-, and 1-inch connectors as listed in Table XI. The conditions described previously for the preliminary tests were repeated. No helium leakage could be detected for any of the connectors pressurized to 4000 psi.

Verification Testing of 21-6-9 Seals

The verification tests selected for the 21-6-9 seals were the load tests, vibration test, and misalignment test. These are described briefly.

Load Tests. All of the seals of the three candidate-materials that had been load tested during the preliminary tests had been machined with modified inside diameters to simulate the theoretical minimum and maximum yield strengths. For the verification tests of the 21-6-9 seals, it was decided that the inside diameters of the basic design would be used so a more direct comparison could be made between the calculated radial sealing forces and the measured radial sealing forces. This approach permitted a more direct determination of the accuracy of the radial-load-calculating procedure for the three seal sizes, i.e., 1/2, 3/4, and 1 inch.

The test seals were machined to the dimensions shown in MS 27855, with the disk and tang dimensions increased as shown in Table VI. The seals were nickel plated in accordance with MIL-P-27418 (USAF). Table XIV shows the results of the verification load tests for 21-6-9 seals. As shown in Table XIV, the results indicated that the method for calculating radial sealing loads becomes more accurate as the seal size increases. This can also be observed in Table XIII, which shows the results of the verification load tests for the 304 seals.

TABLE XIV. VERIFICATION LOAD-TEST RESULTS FOR 21-619 SEALS

Tubing Size, in.	Available Axial Assembly Force, lb	Maximum Axial Force, lb	Calculated Radial Sealing Force, lb/in. of seal circumference	Maximum Measured Radial Sealing Force, lb/in. of seal circumference	Average Radial Sealing Force, lb/in. of seal circumference
		1740		1720	
1/2	2800	2100	1471	2120	1870
		1620		1770	
		2820		1540	
3/4	5510	2830	1484	1920	1570
		2820		1250	
		4140		1770	
1	8764	3600	1441	1300	1390
		3570		1100	

Vibration. Vibration tests were conducted with minimum-strength 1/2- and 1-inch seals in accordance with MIL-F-27417 (USAF). One seal of each size was tested. No helium leakage could be detected during the tests.

Misalignment. Misalignment tests were conducted with minimum-strength 1/2-, 3/4-, and 1-inch seals under conditions described previously for the preliminary tests. No helium leakage could be detected for any of the assemblies.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the work described in this report, it was concluded that:

(1) The 304 seal designs selected for verification testing will provide the desired improvements in the performance of 1/2-, 3/4-, and 1-inch AFRPL stainless steel threaded connectors.

(2) The 21-6-9 seal designs selected for partial verification testing will probably provide the desired improvements in the performance of 1/2-, 3/4-, and 1-inch AFRPL stainless steel threaded connectors.

(3) Plating specification MIL-P-27418 (USAF) is satisfactory if the inspection function is modified to include the use of a 5-power glass.

It is therefore recommended that:

(1) MS 27855 be modified to include the modified tang-length and disk-thickness dimensions shown on Table VI.

(2) MS 27855 be modified to limit the existing material specifications to 1/8-, 1/4-, and 3/8-inch seals and to limit the tensile yield strengths to 40,000 psi.

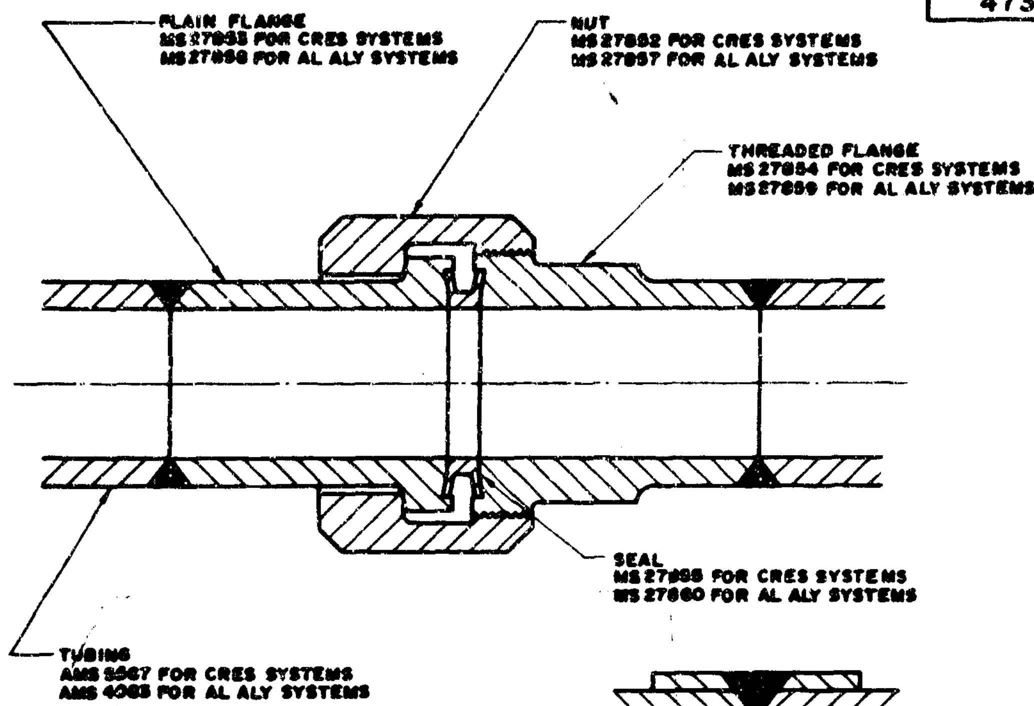
(3) MS 27855 be modified to include the specification of Type 304 stainless steel with a minimum tensile yield strength of 50,000 psi and a maximum tensile yield strength of 70,000 psi for use with the 1/2-, 3/4-, and 1-inch seals.

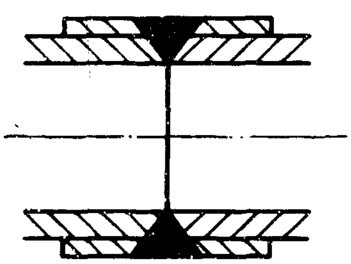
(4) MIL-P-27418 (USAF) be modified to include the use of a 5-power glass in the inspection function.

APPENDIX I

MS STANDARDS FOR AFRPL 4000-PSI STAINLESS STEEL THREADED CONNECTORS

FED. SUP CLASS
4730





OPTIONAL JOINT DESIGN

TUBING TO TUBING FITTING INSTALLATION

DASH NO. REF.		WRENCH TORQUE FOR TIGHTENING CRES FITTINGS (LB/IN) MS27851		WRENCH TORQUE FOR TIGHTENING AL ALY FITTINGS (LB/IN) MS27856	
		MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
-02	1/8	75	90		
-04	1/4	200	225	100	125
-06	3/8	380	435	175	200
-08	1/2	490	556	280	320
-12	3/4	1240	1400	530	600
-16	1	2300	2580	1070	1200

APPROVED 14 JULY 1967 REVISED

Review activities: 11, 14, 19, 69, 88 & NAS

This standard has been approved by the Department of the Air Force and is mandatory for use by that activity. All other military activities are requested to employ this standard where suitable.

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 5

DD FORM 672-1 (Limited coordination) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

FED. SUP CLASS
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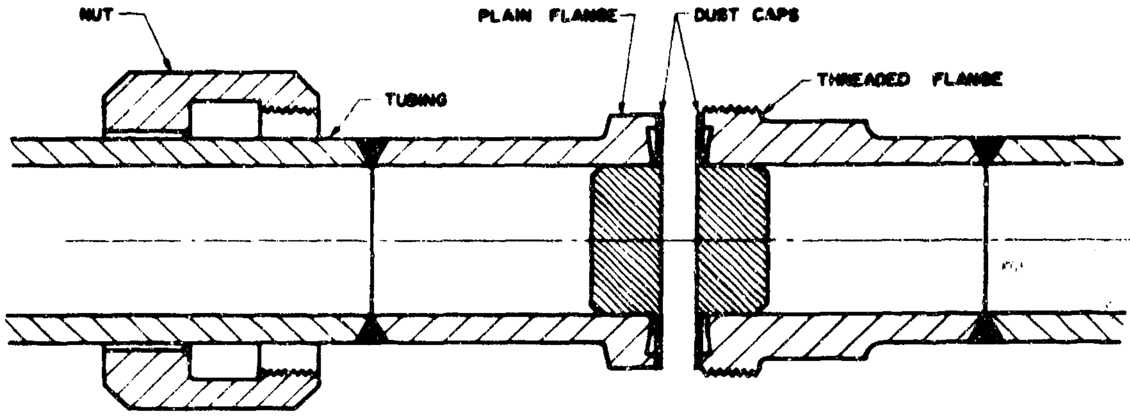
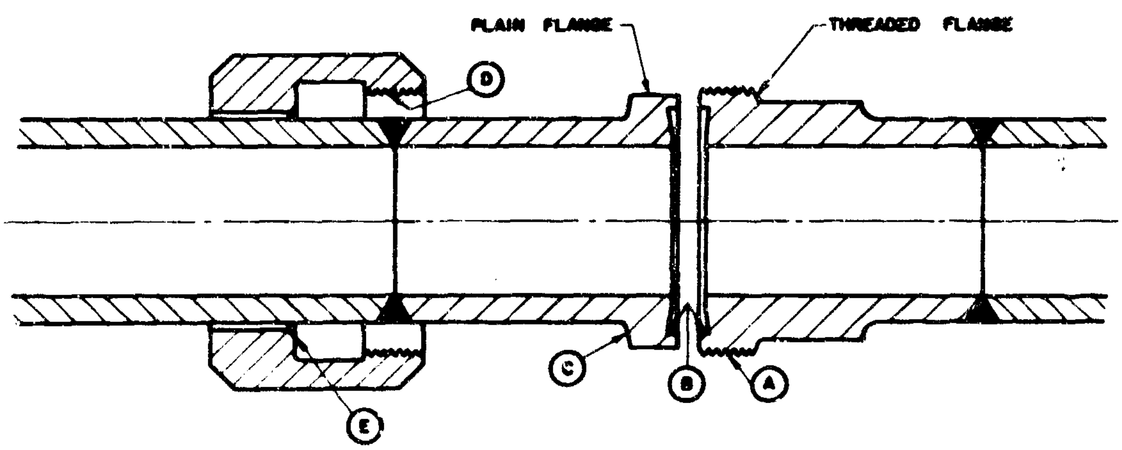


STEP 1

PLACE THE NUT ON THE TUBING TO BE ATTACHED TO PLAIN FLANGE. WELD PLAIN AND THREADED FLANGES TO TUBING.



STEP 2

REMOVE DUST CAPS. INSPECT SURFACES A, B, C, D, AND E FOR DIRT, CONTAMINATION, OR SURFACE IRREGULARITIES. IF NECESSARY RINSE SURFACES WITH METHYLETHYLKETONE AND DRY PARTS WITH FILTERED AIR STREAM OR WIPE PARTS WITH CLEAN PAPER TISSUE MOISTENED WITH METHYLETHYLKETONE. REPLACE DUST CAPS.

Review activities: 11, 14, 18, 68, 85, & NAS

This standard has been approved by the Department of the Air Force and is mandatory for use by that activity. All other military activities are requested to employ this standard where suitable.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 2 OF 3

DD FORM 1 APR 61 672-1 (Limited coordination) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

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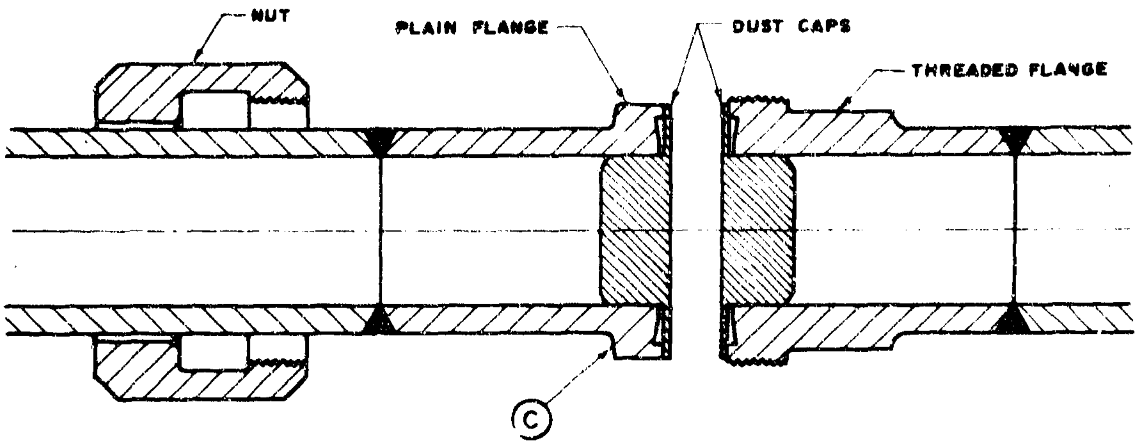
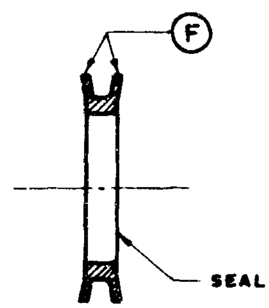


STEP 3

COAT MALE THREADS AND SURFACE C WITH LUBRICANT. APPLY LUBRICANT SPARINGLY. WORK THE NUT ONTO THE MALE THREADS AND AGAINST SURFACE C BY HAND. RETRACT NUT AND INSPECT SURFACES FOR EVEN COATING OF LUBRICANT. REMOVE EXCESS LUBRICANT FROM NONLUBRICATED SURFACES.



STEP 4

REMOVE SEAL FROM PROTECTIVE WRAPPING. INSPECT SURFACES F WITH 10 POWER LENS. DISCARD IF SURFACES ARE SCRATCHED OR IRREGULAR. CLEAN WITH METHYLETHYLKETONE IF DIRTY.

APPROVED 14 JULY 1967 REVISED

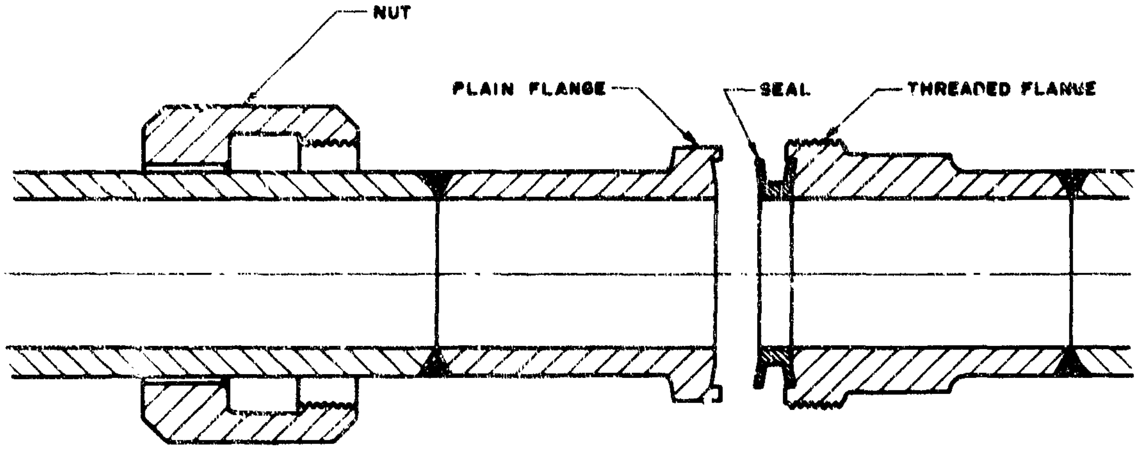
Review activities: 11,14,19,69,88 & NAS

This standard has been approved by the Department of the Air Force and is mandatory for use by that activity. All other military activities are required to employ this standard where suitable.

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 3 OF 3

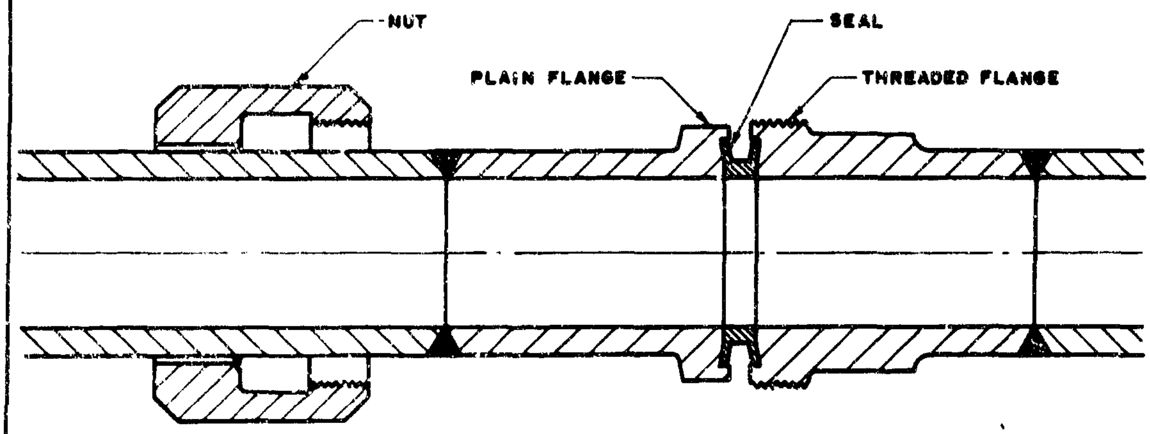
DD FORM 672-1 (Limited coordination) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

FED. SUP CLASS
4730



STEP 5

REMOVE DUST CAPS FROM PLAIN AND THREADED FLANGE AND INSERT SEAL. HANDLING WITH CLEAN HANDS IS PERMISSIBLE BUT CARE MUST BE EXERCISED TO AVOID GETTING LUBRICANT OR DIRT ON THE SEALING SURFACES.



STEP 6

LOCATE PLAIN FLANGE SO SEAL IS RETAINED IN THE SEAL CAVITY OF BOTH FLANGES. MAKE CERTAIN SEAL IS COMPLETELY INSERTED INTO BOTH PLAIN AND THREADED FLANGE SEAL CAVITIES.

Review activities: 11,14,19,69,95 & NAS

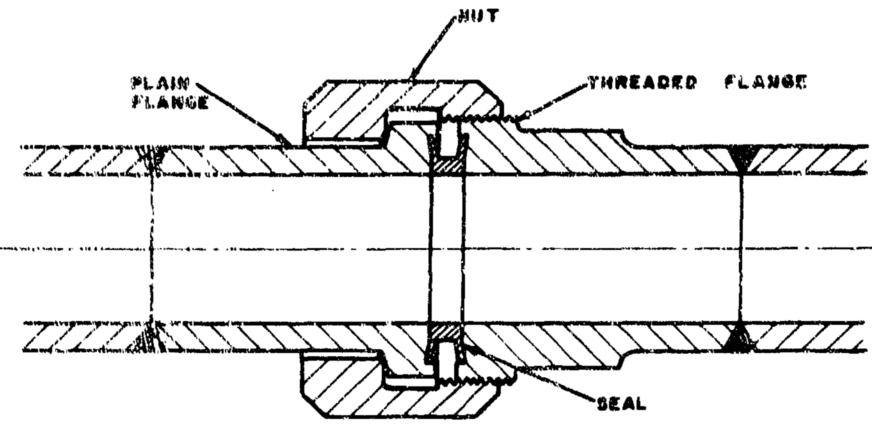
This standard has been approved by the Department of the Air Force and is mandatory for use by that activity. All other military activities are requested to employ this standard where possible.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 4 OF 8

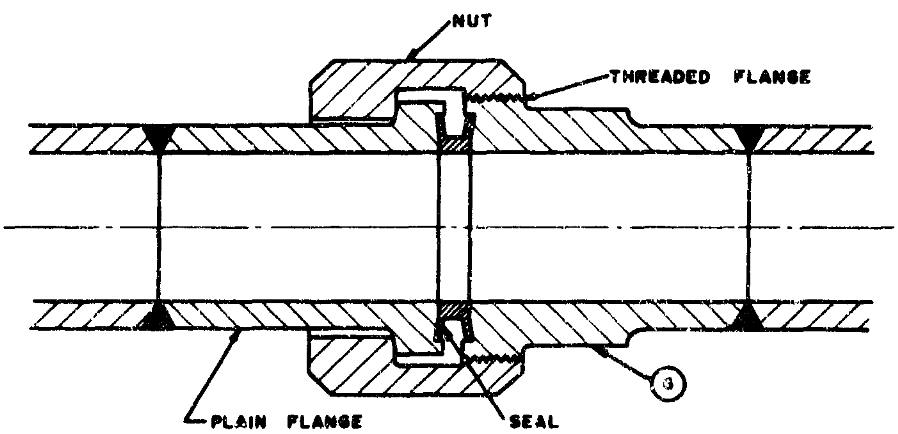
DD FORM 1 SEP 67 672-1 (Limited coordination) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

FED. SUP CLASS 4730



STEP 7

TIGHTEN NUT HAND-TIGHT WHILE MAINTAINING LIGHT, FIRM PRESSURE ALONG AXIS OF FITTING TO PREVENT SEAL FROM SLIPPING OUT OF FLANGE CAVITIES.



STEP 8

PLACE OPEN-END WRENCH ON THREADED FLANGE, SURFACES 6 AND HOLD OR ALLOW TO BEAR AGAINST RIGID STRUCTURE TO PREVENT ROTATION. TIGHTEN NUT WITH CALIBRATED TORQUE WRENCH TO RECOMMENDED TORQUE. IF EITHER FLANGE HAS RELATIVE ROTATION MORE THAN 1/16 TURN, DISASSEMBLE AND REPLACE SEAL. PROPER ASSEMBLY IS INDICATED BY THREAD ENGAGEMENT. NO MORE THAN ONE THREAD OF EITHER THE THREADED FLANGE OR NUT SHOULD BE EXPOSED.

Review activities: 11, 14, 19, 68, 55, 8 NAS

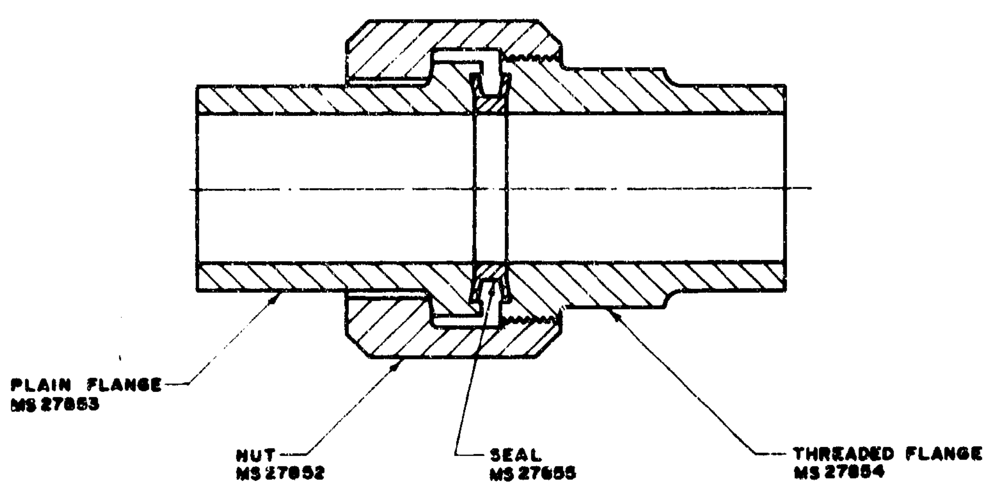
APPROVED 14 JULY 1967 REVISED

THIS STANDARD HAS BEEN APPROVED BY THE DEPARTMENT OF THE AIR FORCE AND IS MANDATORY FOR USE BY THAT ACTIVITY. ALL OTHER MILITARY ACTIVITIES ARE REQUIRED TO EMPLOY THIS STANDARD WHERE SUITABLE.

P.A. USAF 12 Other Cust	TITLE FITTINGS, INSTALLATION OF STRAIGHT THREADED FLUID CONNECTION	MILITARY STANDARD MS 27850 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 5 OF 5

DD FORM 1 SEP 59 672-1 (LIMITED COORDINATION) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

FED. SUP CLASS
4730



MS ASSEMBLY NO.	TUBE O.D.	NUT	PLAIN FLANGE	THREADED FLANGE	SEAL
MS 27851-02	1/8	MS 27852-02	MS 27853-02	MS 27854-02	MS 27855-02
MS 27851-04	1/4	MS 27852-04	MS 27853-04	MS 27854-04	MS 27855-04
MS 27851-06	3/8	MS 27852-06	MS 27853-06	MS 27854-06	MS 27855-06
MS 27851-08	1/2	MS 27852-08	MS 27853-08	MS 27854-08	MS 27855-08
MS 27851-12	3/4	MS 27852-12	MS 27853-12	MS 27854-12	MS 27855-12
MS 27851-16	1	MS 27852-16	MS 27853-16	MS 27854-16	MS 27855-16

1. DO NOT USE UNASSIGNED PART NUMBERS.
2. REFER TO MS 27850 FOR INSTALLATION INSTRUCTIONS.
   FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
   REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

Review activities: 11, 14, 19, 69, 85 & NAS

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FITTING ASSEMBLY, STRAIGHT THREADED, FLUID CONNECTION, 4000 PSI	MILITARY STANDARD MS 27851 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

DD FORM 672-1 (Limited coordination)

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

FED. SUP CLASS
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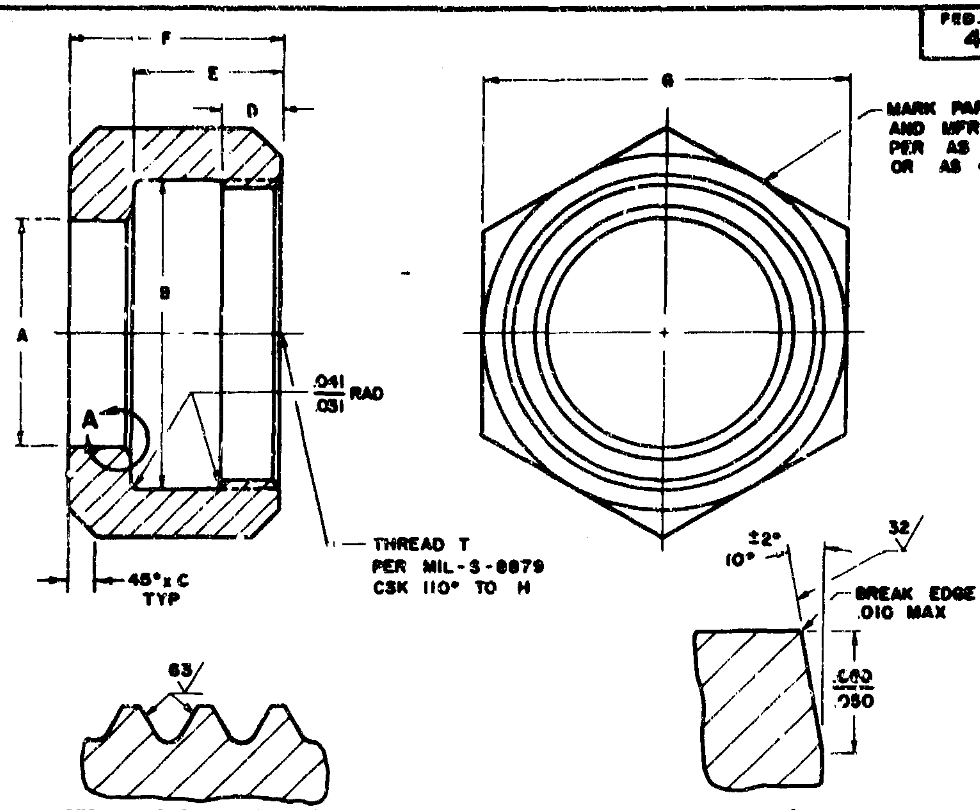


SECTION THRU THREAD PROFILE

VIEW A

MS PART NO.	TUBE O. D.	THREAD T UNJEF - 3B	A DIA ±.005	B DIA ±.004	C	D ±.005	E ±.005	F	G +.002 -.006	H DIA	APPROX WEIGHT LB/EA
MS27852 -02	1/8	9/16 -24	.277	.563	.057	.213	.584	.720	.625	.562	
MS27852 -04	1/4	5/8 -24	.375	.624	.056	.213	.576	.782	.688	.625	.034
MS27852 -06	3/8	3/4 -20	.491	.752	.071	.255	.625	.903	.812	.750	.051
MS27852 -08	1/2	7/8 -20	.593	.877	.082	.255	.635	.908	.938	.875	.066
MS27852 -12	3/4	1-1/8 -18	.820	1.127	.101	.283	.658	1.006	1.180	1.125	.113
MS27852 -16	1	1-5/16 -18	1.070	1.375	.120	.283	.616	1.081	1.438	1.312	.168

1. THREAD PD, HEX, A DIA AND B DIA, SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: CORROSION RESISTANT STEEL AMS 5735.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

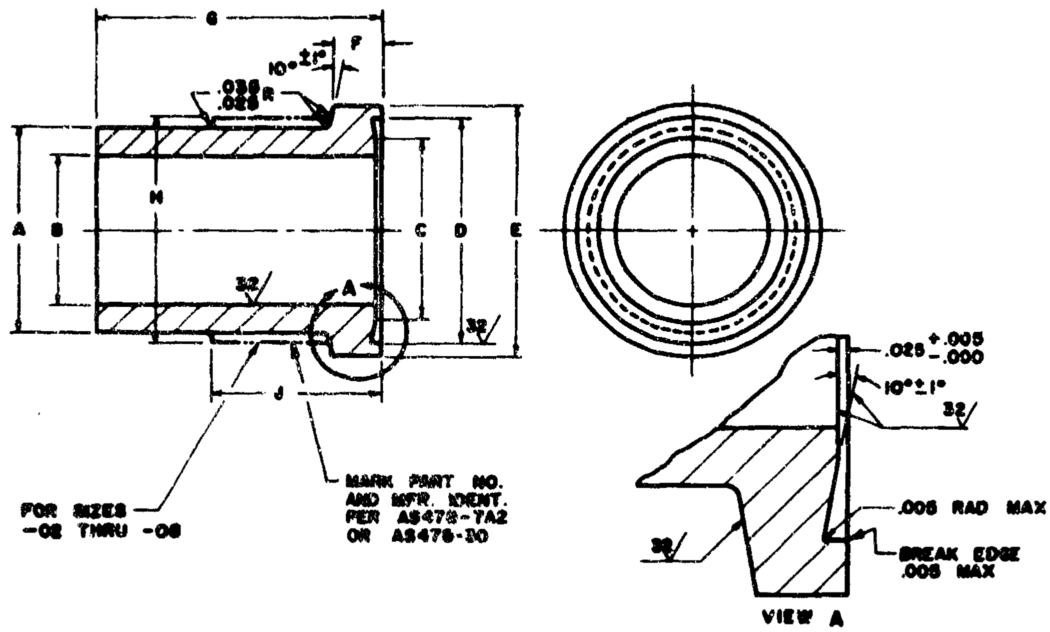
Review activities: 11, 14, 19, 69, 3C, & MA3

This standard has been approved by the Department of the AIR FORCE and is mandatory for use by that activity. All other military activities are required to employ this standard if one is suitable.

P.A. USAF 12 Other Cust	TITLE NUT, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27852 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

DD FORM 1 OCT 60 672-1 (Limited coordination)   PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

FED. SUP CLASS 4730



MS PART NO.	TUBE O.D.	A DIA	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E DIA +.002 -.007	F ±.005	G	H DIA +.005 -.000	J ±.031	APPROX. WEIGHT LB/EA
MS27853-02	1/8	.125±.002	.063	.186	.360	.500	.313	1.125	.217	.440	
MS27853-04	1/4	.250±.003	.178	.260	.452	.562	.280	1.125	.319	.467	.027
MS27853-06	3/8	.375±.003	.275	.372	.564	.694	.258	1.250	.431	.503	.039
MS27853-08	1/2	.500±.004	.368	.470	.666	.806	.267	1.250	.533	.531	.067
MS27853-12	3/4	.750±.004	.560	.694	.888	1.048	.263	1.375	—	—	.104
MS27853-16	1	1.000±.005	.730	.904	1.100	1.236	.225	1.375	—	—	.163

1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .005 FIR.
2. MATERIAL: CORROSION RESISTANT STEEL AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003 - .013 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.

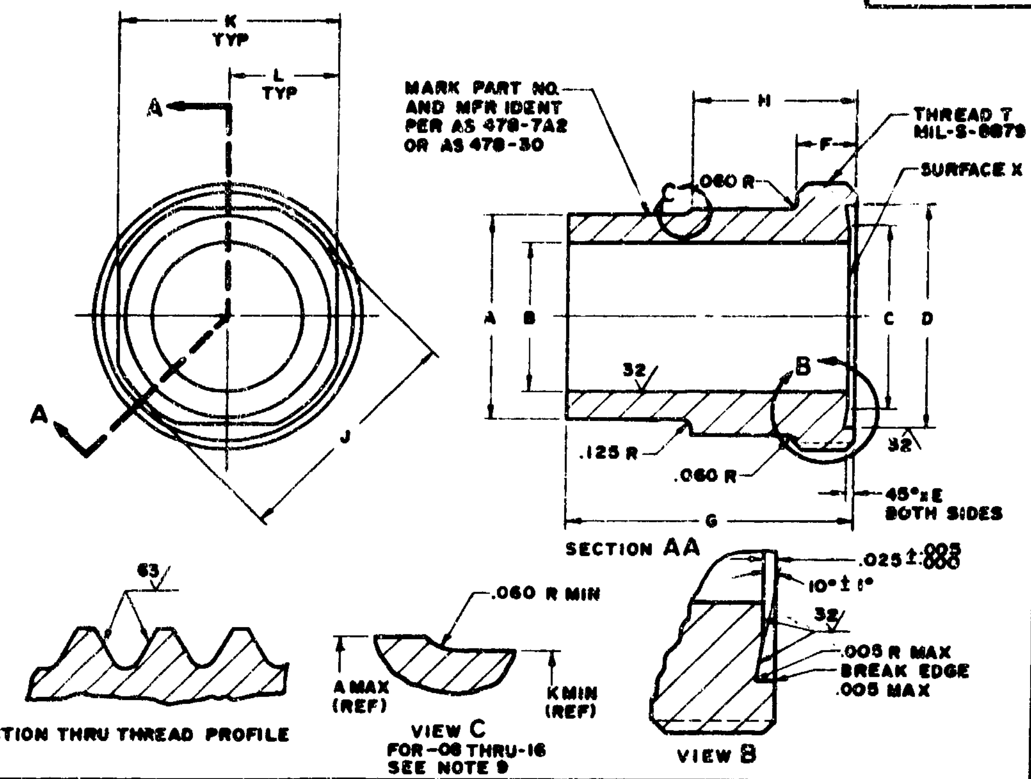
FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE FLANGE, PLAIN, CRES, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27853 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

DD FORM 672-1 (Limited coordination)   PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

FED. SUP CLASS
4730



MS PART NO.	TUBE O.D.	THREAD T UNJEF-3A	A DIA	B DIA ±.002	C DIA +.000 -.010	D DIA +.002 -.000	E	F ±.005	G	H ±.031	J DIA	K +.002 -.006	L	APPROX WEIGHT LB/EA
MS 27854-02	1/8	9/16-24	.125±.002	.003	.156	.350	.030	.213	1.125	.463	.300	.250	.125	
MS 27854-04	1/4	5/8-24	.250±.003	.178	.260	.452	.030	.213	1.125	.463	.361	.312	.156	.024
MS 27854-06	3/8	3/4-20	.375±.003	.275	.372	.564	.035	.255	1.250	.567	.505	.437	.218	.046
MS 27854-08	1/2	7/8-20	.500±.004	.368	.470	.666	.035	.255	1.250	.630	.577	.500	.281	.066
MS 27854-12	3/4	1-1/8-18	.750±.004	.558	.694	.888	.040	.283	1.375	.720	.866	.750	.406	.128
MS 27854-16	1	1-5/16-18	1.000±.005	.730	.904	1.100	.040	.283	1.375	.783	1.155	1.000	.531	.161

1. THREAD PD SHALL BE SQUARE WITH SURFACE X WITHIN .005 FIR AND CONCENTRIC WITH DIA D WITHIN .005 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5646.
3. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
4. SURFACE TEXTURE, IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, ALL MACHINED SURFACES TO BE 63 MICROINCHES.
5. BREAK EDGES .003-.015 UNLESS OTHERWISE SPECIFIED.
6. DIMENSIONS IN INCHES, UNLESS OTHERWISE SPECIFIED, TOLERANCES: DECIMALS ±.010, ANGLES ±5°.
7. DO NOT USE UNASSIGNED PART NUMBERS.
8. REFER TO MS27851 FOR ASSEMBLY.
9. BLEND WRENCH FLATS K INTO DIA A AS SHOWN IN VIEW C, WHEN K IS LESS THAN A.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.

REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

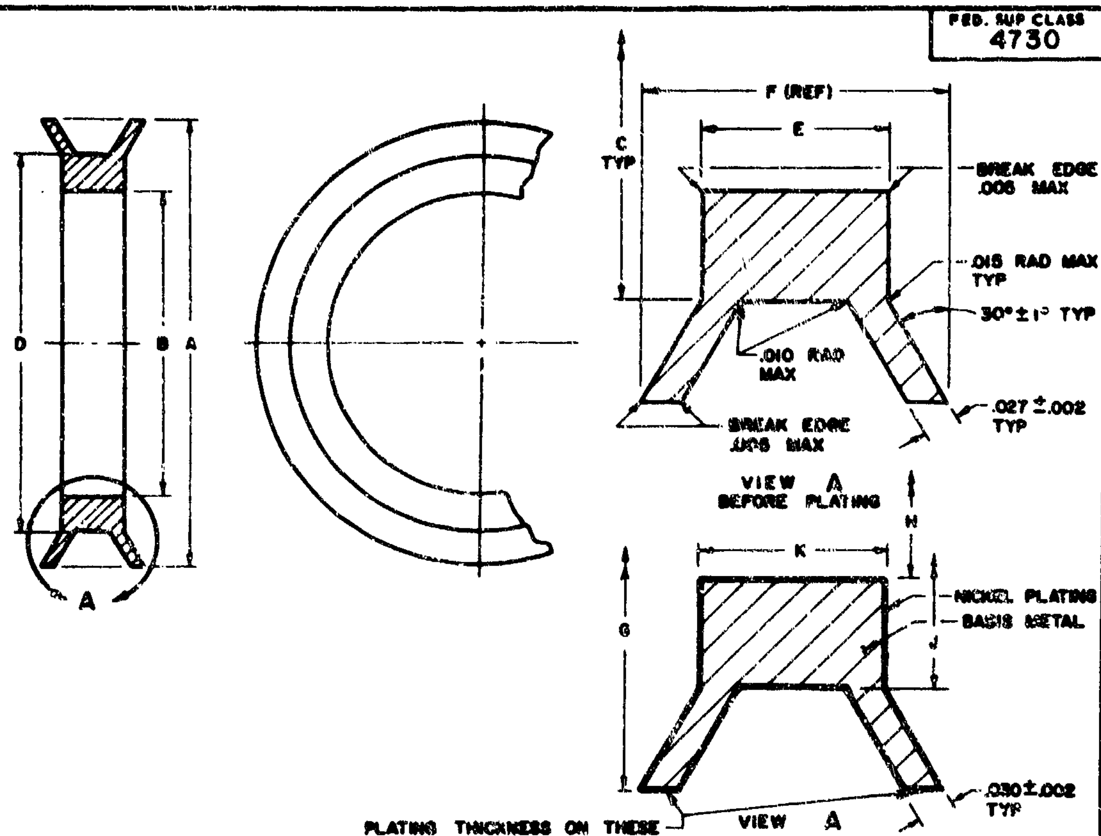
APPROVED 14 JULY 1967 REVISED

Review activities: 11, 14, 19, 69, 85 & NAS

This standard has been approved by the Department of the AIR FORCE and is mandatory for use by that activity. All other military activities are requested to employ this standard where suitable.

P.A. USAF 12 Other Cust	TITLE FLANGE, THREADED, CRES., FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS 27854 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES:	SHEET 1 OF 1

DD FORM 1 SEP 64 672-1 (Limited coordination)   PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.



MS PART NO.	TUBE O.D.	A DIA +.000 −.002	B DIA +.002 −.000	C DIA +.010 −.000	D DIA +.000 −.008	E ±.004	F REF	G DIA +.001 −.005	H DIA +.002 −.000	J DIA +.000 −.008	K ±.004	APPROX. WEIGHT LB/100
MS27855-02	1/8	.342	.100	.172	.174	.095	.193	.348	.098	.178	.099	
MS27855-04	1/4	.444	.190	.274	.276	.120	.218	.450	.186	.280	.124	.220
MS27855-06	3/8	.566	.290	.386	.389	.150	.248	.562	.288	.393	.154	.440
MS27855-08	1/2	.658	.382	.488	.491	.150	.248	.664	.378	.496	.154	.500
MS27855-12	3/4	.880	.572	.710	.713	.150	.248	.886	.568	.717	.154	.890
MS27855-16	1	1.092	.744	.922	.925	.150	.248	1.098	.740	.929	.154	1.550

1. ALL DIAMETERS SHALL BE CONCENTRIC WITHIN .002 FIR.
2. MATERIAL: CORROSION-RESISTANT STEEL, AMS 5639, AMS 5650 OR AMS 5651.
3. FINISH: NICKEL PLATING PER MIL-P-27418.
4. CLEANING: FINISHED PARTS SHALL BE CLEANED PER MIL-F-27417.
5. SURFACE TEXTURE IN ACCORDANCE WITH USAS B46.1, UNLESS OTHERWISE SPECIFIED, SURFACES TO BE 32 MICROINCHES BEFORE PLATING.
6. BREAK SHARP EDGES .003 - .015 UNLESS OTHERWISE SPECIFIED.
7. DIMENSIONS IN INCHES. UNLESS OTHERWISE SPECIFIED, TOLERANCES: LINEAR DIMENSIONS ±.010, ANGULAR DIMENSIONS ± 5°.
8. RUBBER STAMP P/N AND MFR IDENT ON CONTAINER OR PACKAGING PER AS 478-30.
9. DO NOT USE UNASSIGNED PART NUMBERS.
10. REFER TO MS27851 FOR ASSEMBLY.

FOR DESIGN FEATURE PURPOSES, THIS STANDARD TAKES PRECEDENCE OVER PROCUREMENT DOCUMENTS REFERENCED HEREIN.
REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

APPROVED 14 JULY 1967 REVISED

P.A. USAF 12 Other Cust	TITLE SEAL, CRES, NICKEL PLATED, FLUID CONNECTION FITTING, HIGH PRESSURE	MILITARY STANDARD MS27855 (USAF)
PROCUREMENT SPECIFICATION MIL-F-27417	SUPERSEDES	SHEET 1 OF 1

Review activities: 11, 14, 19, 69, 86, 8 MAS

This standard has been approved by the Department of the Air Force and is mandatory for use by that activity. All other activity agencies are required to employ this standard when suitable.

DD FORM 1 OCT 66 672-1 (Limited coordination) PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

APPENDIX II

MIL-P-27418 (USAF) MILITARY SPECIFICATION, PLATING, SOFT NICKEL (ELECTRODEPOSITED, SULFAMATE BATH)

MILITARY SPECIFICATION

PLATING, SOFT NICKEL (ELECTRODEPOSITED, SULFAMATE BATH)

1. SCOPE

1.1 Scope. This specification covers the processes and requirements for soft nickel plating.

2. APPLICABLE DOCUMENTS

Not applicable

3. REQUIREMENTS

3.1 Materials. The materials used shall be such as to produce coatings which meet the requirements of this specification.

3.2 Workmanship.

3.2.1 Basis metal. The basis metal shall be free from visible defects that will be detrimental to the performance of the plating. Articles to be plated shall be stress relieved, cleaned, etched, pickled, plated, and annealed as required to produce plating as specified herein.

3.2.2 Plating. The nickel plating shall be smooth, columnar crystalline (before annealing - 6.3), adherent, and free from visible blisters, pits, nodules, porosity, indications of burning and excessive edge buildup, and other defects. Slight discoloration resulting from annealing, shall not be cause for rejection. All details of workmanship shall conform to the best practice for high-quality plating.

3.3 General requirements.

3.3.1 Unless otherwise specified, the plating shall be applied after all basis-metal heat treatments and mechanical operations such as machining, brazing, welding, forming, and perforating on the article have been completed.

3.3.2 All articles shall be given a suitable stress-relief heat treatment prior to cleaning and plating. The temperature shall be such that maximum stress relief is obtained without reduction in hardness to less than the specified minimum.

FSC MISC

3.3.3 Unless otherwise specified, the plating shall be electrodeposited in an all-sulfamate, chloride-free nickel bath (6.3).

3.3.4 All articles shall be annealed in a vacuum furnace after plating to obtain the proper plating hardness.

3.4 Detail requirements.

3.4.1 Plating thickness. Unless otherwise specified, the plating shall be 0.0020 inch ± 0.0003 inch thick on all surfaces to be plated which can be touched by a ball 1/16 inch in diameter.

3.4.2 Plating boundaries. Unless otherwise specified, boundaries of the plating which covers only a portion of the surface shall be free from beads, nodules, jagged edges, and other irregularities, and shall blend smoothly into the unplated surface.

3.4.3 Plating hardness. Unless otherwise specified, the Knoop hardness of the plating after annealing shall not exceed 150 with a 500-gram load.

3.4.4 Plating adhesion. When examined at a magnification of approximately 4 diameters, adhesion of the nickel plating shall not show separation from the basis metal when subjected to the test specified in 4.4.2. The formation of cracks in the basis metal which do not result in flaking, peeling, or blistering of the coating shall not be considered as nonconformance to this requirement.

3.4.5 Process deviations. Deviations from the specified plating and annealing requirements of this specification may be authorized by the Government inspector or the procuring activity provided the contractor demonstrates that coatings thus produced are equivalent (6.3), for the purpose intended, to coatings produced under the specified conditions. Doubtful cases shall be referred to the procuring activity for decision.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified by the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Separate specimens. When the plated articles are of such form as to be not readily adaptable to a test specified herein, or at the discretion of the inspector for destructive tests for the sampling of small lot sizes, or as otherwise specified herein, the test shall be made by the use of spearate specimens plated and annealed concurrently with the articles represented. The separate specimens shall be of a basis metal equivalent to that of the articles represented. "Equivalent" basis metal includes chemical composition, heat treatment, and finish of surface prior to plating. Due to the impracticability of forging separate test specimens, equivalent hot-rolled steel specimens may be used to represent forged steel articles. The separate specimens shall be strips approximately 1 inch wide, 4 inches long, and 0.04 inch thick. These specimens shall be introduced into a lot prior to the cleaning operations preliminary to plating and annealing processes. Conditions affecting the plating and annealing of the specimens including the spacing and positioning with respect to anodes and to other objects being plated, and with respect to the heating surfaces, shall correspond as nearly as possible to those affecting the significant surfaces of the articles represented.

4.3 Sampling.

4.3.1 Lot. A lot shall consist of plated articles of approximately the same size and shape, plated and annealed concurrently and submitted for inspection at one time. Lot size shall not exceed 500 articles.

4.3.1.1 Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order.

4.3.2 Sampling procedures for visual examination. A sample shall be taken from each lot by taking at random from the lot the number of articles indicated in table I. The lot shall be accepted or rejected on the basis of the sample according to the procedures in 4.3.2.1.

TABLE I

Sampling for visual inspection

Number of articles in lot	Number of articles in sample (randomly selected)	Acceptance number= (maximum number of sample articles nonconforming to any test)
15 or less	1/ 7	0
16 to 40	10	0
41 to 110	15	0
111 to 300	25	1
301 to 500	35	1

1/ If the number of articles in the lot is less than 7, the number or articles in the sample shall equal the number of articles in the lot.

4.3.2.1 Visual inspection. The number of sample articles indicated in table I shall be taken at random from the lot to be inspected and examined visually and compared with requirements of 3.2.2 after annealing. If the number of nonconforming articles in any sample exceeds the acceptance number for that sample, the lot represented by the sample shall be rejected.

4.3.3 Sampling procedure for hardness, adhesion, and coating thickness tests. A small, random sample of articles shall be selected from each lot by the Government inspector and three separate specimens shall be prepared in accordance with 4.2 to represent each lot. The number of articles in the sample shall be determined by the procuring activity or shall be left to the discretion of the inspector. Each randomly selected sample article shall be subjected to the thickness test and each of the three separate specimens shall be subjected to the hardness, adhesion, and thickness tests.

4.3.3.1 Hardness. Each specimen shall be tested in accordance with 4.4.1 in several locations at which the plating hardness would be expected to be maximum. If the hardness at any place on any specimen is greater than the specified hardness, the lot shall be rejected.

4.3.3.2 Adhesion. Each specimen shall be tested in accordance with 4.4.2. Failure of one or more of the test specimens shall constitute failure of the lot.

4.3.3.3 Thickness (destructive test). Each article and specimen shall be tested in accordance with 4.4.3 in several locations at which the plating thickness would be expected to be minimum. If the plating thickness at any place not affected by the hardness or adhesion tests is greater than or less than the specified thickness limits, the lot shall be rejected.

4.4 Test methods.

4.4.1 Hardness. Standard hardness testing procedures shall be used to determine the Knoop hardness of the coating within $\pm$ 5 percent of its true hardness.

4.4.2 Adhesion. The test specimens shall be bent repeatedly through an angle of 180 degrees on a diameter equal to the thickness of the specimen until fracture of the basis metal occurs. Following fracture of the basis metal, it shall not be possible to detach any appreciable areas of the coating with a sharp instrument.

4.4.3 Thickness. Standard metallographic procedures shall be used to determine the coating thickness with a microscope. The specific method and equipment used shall be such that the coating thickness shall be determined within $\pm$ 10 percent of its true thickness.

4.5 Replating. Unless otherwise specified, plated articles which have been rejected or withdrawn because of the presence of plating defects may be resubmitted after stripping, replating, and reannealing the entire lot. Complete details of the replating and reannealing shall be furnished to, and be approved by, the inspector or procuring activity.

5. PREPARATION FOR DELIVERY

5.1 There are no general packaging, packing, or marking requirements applicable to this specification. Packaging when required shall be as specified by the procuring activity.

6. NOTES

6.1 Intended use. The plating conforming to this specification is intended to facilitate the formation of a seal between two metallic surfaces.

6.2 Ordering data. Requisitions, contracts, and orders should be accompanied by drawings of the articles to be plated. The procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Instructions concerning the areas to be plated, deviations from the specified plating thickness, and any other necessary information pertinent to the plated surfaces.

(c) Instructions concerning the number of articles to be selected for the thickness test (4.3.3).

(d) Instructions concerning samples for approval (6.6).

6.3 Plating type. According to considerable laboratory testing, the nickel plating best suited to creating a seal when yielded against a metallic surface has a columnar crystalline structure before annealing. This structure is illustrated in figure 1. When a process other than the one specified is recommended by the contractor, the resulting structure of the plating before annealing should closely approximate the structure shown in figure 1.

6.4 Plating hardness. The acceptance of the plating is determined according to this specification by tests made after annealing. However, when the Knoop hardness of the plating prior to annealing is less than 300 with a 500-gram load, the eventual acceptability of the plating after annealing is indicated (3.4.3).

Figure 1. Columnar crystalline structure of soft nickel plating prior to annealing. (500X)

6.5 Plating thickness. The dimensional tolerances of most seals do not allow for wide variations in plating thickness. The plating thickness covered by this specification (0.0020 inch) has been selected to provide maximum uniformity and minimum shear stresses during deformation. When other thicknesses are desired, adequate tests must be made to determine the performance of the desired thickness.

6.6 Samples. This specification describes the characteristics necessary to secure the desired plating. Unless otherwise specified, no samples will be necessary prior to award to determine compliance with this specification. If, for any particular purpose, samples with bids are necessary, they should be specifically asked for in the invitation for bids, and the particular purpose to be served by the bid sample should be definitely stated, the specification to apply to all other respects.

Custodians:

Air Force - 12

Review activities:

Air Force - 11, 14, 19, 69, 85

Civilian Agencies Interest:

NAS

Preparing Activity:

Air Force - 12

Reviewer/user information is current as of the date of this document. For further coordination of changes to this document, draft circulation should be based on the information in the current DoD Index of Specifications and Standards.

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SPECIFICATION ANALYSIS SHEET	Form Approved Budget Bureau No. 119-R004

INSTRUCTIONS

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity (as indicated on reverse hereof).

SPECIFICATION

MIL-P-27418 Plating, Soft Nickel (Electrodeposited, Sulfamate Bath)

ORGANIZATION *(Of submitter)*		CITY AND STATE
CONTRACT NO.	QUANTITY OF ITEMS PROCURED	DOLLAR AMOUNT $

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

A. GIVE PARAGRAPH NUMBER AND WORDING.

B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES.

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

☐ YES ☐ NO IF "YES", IN WHAT WAY?

4. REMARKS *(Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity)*

SUBMITTED BY *(Printed or typed name and activity)*	DATE

DD FORM 1 APR 63 1426 REPLACES NAVSHIPS FORM 4863, WHICH IS OBSOLETE C-8272

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Director

Air Force Rocket Propulsion Laboratory (RPPS)

Edwards, California 93523

FOLD

APPENDIX III

INTERIM, 3-MONTH RESULTS OF AFRPL CORROSION COMPATIBILITY TESTING

AFRPL-TM-70-8

MATERIALS/PROPELLANT COMPATIBILITY PROGRAM

(UNCLASSIFIED)

H. Rede

April 1970

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This Technical Memorandum has been reviewed and approved

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FOREWORD

The Liquid Rocket Division of the AFRPL initiated a research evaluation under Project 314802BCR to perform a series of corrosion compatibility tests. The data generated from this investigation are required as an input to Contract F04611-69-C-0028 to determine an effective bobbin seal material for application in AFRPL threaded connectors.

The author wishes to acknowledge the very able technical assistance afforded him by personnel of the Chemical & Materials Branch of the Air Force Rocket Propulsion Laboratory. Special thanks are in order to the following people: Major R. Schalow and Airman G. Whiting for the metallurgical discussions concerning all aspects of the program; Sgt D. Conatser, T. Owens, and L. Dee for their assistance in designing and operating the ClF_3 "Transfer" station; and to Mr. J. T. Nakamura for his guidance and supervision during the conduct of this program.

MATERIALS/PROPELLANT COMPATIBILITY PROGRAM

(Interim 3-month Report)

I. INTRODUCTION

An effective bobbin seal, compatible with nitrogen tetroxide (N_2O_4) and chlorine trifluoride (ClF_3), for application in the AFRPL threaded connector is required. The selected materials were 19-9DL, ARMCO 21-6-9, and cold rolled 304 stainless steel obtained in sheet form from Battelle Memorial Institute. Coupons of the three materials were totally immersed in liquid N_2O_4 (Mil Spec No. 9135-926-2165) and ClF_3 (purchased from J. T. Baker Co., Torrance, California), respectively, at a temperature of 160°F. Data for non-plated and nickel-plated specimens of the above materials were required.

II. EXPERIMENTAL PROCEDURE

A. Preparation Technique.

Unstressed coupons (Fig. 1), abraded with 240 grit paper to remove the mill finish, were used to determine the type of corrosion attack, i.e., general, pitting, or intergranular. U-bend specimens

were used to test stress corrosion susceptibility. (Fig. 2) Care was taken in the shaping of the coupons so that as soon as the U was formed the retainer strip was inserted to preclude relaxation of the stresses applied.

Two types of test containers were used: ten ounce glass bottles for the N_2O_4 test and 347 SS containers with all metal-packing valves for the ClF_3 test. Figures 3 and 4 picture the test set-ups, respectively. The glass bottles and caps were ultrasonically cleaned in an acid solution, rinsed in acetone, and oven-dried at 80°C. The 347 SS containers were vapor degreased, acid cleaned in H_3PO_4, electropolished, rinsed in distilled water, and dried in gaseous nitrogen. Prior to the start of the ClF_3 program, the 347 SS containers plus test specimens were passivated with gaseous ClF_3 for at least 24 hours.

B. Weighing Technique.

1. Before Test

All of the test coupons were rinsed with acetone, blown dry in a gaseous nitrogen atmosphere, placed in a drying oven at 80°C for approximately one-half hour, then left in a dessicator overnight. The coupons were then removed from the dessicator with Teflon-tipped tweezers and weighed to an accuracy of ± 0.0001 gms.

2. After Test

a. N_2O_4 Procedure - The coupons were removed from the glass bottle containers with Teflon-tipped tongs and immediately submerged into a beaker of freon. The same weighing procedure was

then followed, i.e., the coupons were dried in a gaseous nitrogen atmosphere, oven dried, and left in a dessicator overnight. They were then weighed in the same balance previously used.

b. ClF_3 Procedure - The ClF_3 was disposed of in a specially designed "transfer" station. The stainless steel container with the specimen was then purged with gaseous nitrogen. The container was evacuated, then completely submerged in a large bucket of freon. The freon was then allowed to be "sucked" into the container. (This precluded exposing the coupons to the atmosphere upon removal). The coupons were then removed with Teflon-tipped tongs from the freon-filled container, dried in a gaseous nitrogen atmosphere, and the same pre-weighing steps as mentioned above were followed.

C. <u>Examination Technique</u>

Corrosion data were obtained on the basis of weight change, and visual, optical, and metallographic examination. A stereo-zoom microscope (5X to 25X) was used for the optical examination. The metallographic examination included magnifications from 80X to 200X.

Exposure times for the different test specimens are shown in Table I.

Table I EXPOSURE TIMES*

Material	4 Wks	12 Wks	24 Wks	Remarks
19-9DL	A-B	A-B	A-B	A = Non-Plated
Armco 21-6-9	A-B	A-B	A-B	B = Nickel-Plated
304	A-B	A-B	A-B	

Material	Weeks						Remarks
	1	4	8	12	16	24	
19-9DL	U	U	U	U	U	U	U-bend specimens
Armco 21-6-9	U	U	U	U	U	U	for stress corrosion
304	U	U	U	U	U	U	testing

*NOTE: The above test plan was used for both the N_2O_4 and ClF_3 testing.

IV. RESULTS AND DISCUSSIONS

A. N_2O_4 Test - After three months of testing, the non-plated coupons show no evidence of corrosion. In addition, the weight change of these coupons after test is considered negligible (Table II).

The nickel-plated coupons were almost completely covered with a lime-green semi-adherent corrosion product identified by x-ray analysis to be $Ni(NO_3)_2 \cdot XH_2O$, where X = 2, 4, & 6; X = 6 was the predominant type. The first nickel-plated coupons were removed after 4 weeks of test. The average weight gain was 0.06 ± 0.01 gms. The 12-week nickel-plated coupons had an average weight gain of 0.04 ± 0.01 gms. It appears, therefore, that there is no additional weight gain after the initial gain that occurs within a 4-week period.

The U-bend specimens show no evidence of stress corrosion cracking to date.

It appears from the data gathered in the past three months, that the three types of stainless steels in the unplated condition are compatible with N_2O_4 under the test conditions described. The nickel-plated coupons, however, are considered incompatible due to the formation of the lime-green nickel nitrate corrosion product.

B. ClF_3 Test - There has been no evidence of corrosion, including stress corrosion cracking, on any of the test specimens. In addition, the weight change averaged ±0.004 ± 0.0001 gms. which is considered

negligible. (Table II) The only change to report is a slight bluish tint on the unplated specimens. The nickel-plated specimens have not changed from their original appearance.

It appears so far that the three candidate stainless steels are compatible with ClF_3 in both the plated and unplated conditions.

Table II. WEIGHT CHANGES

Legend: A = 304 CRES
B = 19-9DL
C = Armco 21-6-9

Example:
-NP (Non-plated)
A-1-P (Ni-plated)
-U (U-bend)

Type Steel
Specimen No.

I. N_2O_4 Test

Sample	Test Period (wks)	Initial Wt. (Gms)	Wt. Change	Remarks
A-1-NP	4	8.5398	+0.0001	
A-2-NP	12	8.5291	-0.0004	
A-3-NP	24	8.5926		Still in Test
A-4-P	4	7.3454	+0.0733	
A-5-P	12	7.4850	+0.0390	
A-6-P	24	7.7169		Still in test
B-1-NP	4	9.2352	-0.0002	
B-2-NP	12	9.1835	-0.0071	
B-3-NP	24	9.2099		Still in Test
B-4-P	4	8.1735	?	Bottle broke during test
B-5-P	12	8.3627	+0.0478	
B-6-P	24	8.1564		Still in Test
C-1-NP	4	8.4897	-0.0002	
C-2-NP	12	8.4030	+0.0001	
C-3-NP	24	8.4776		Still in test
C-4-P	4	7.3838	+0.0613	
C-5-P	12	7.4227	+0.0628	
C-6-P	24	7.3628		Still in test

NOTE: U-bend specimens were not weighed.

II. ClF_3 Test

Sample	Test Period (wks)	Initial Wt. (Gms)	Wt. Change	Remarks
A-13-NP	4	8.5806	+0.0004	
A-14-NP	12	8.8896	-0.0004	
A-15-NP	24	8.6410		Still in test
A-16-P	4	7.4856	+0.0002	
A-17-P	12	7.4247	+0.0001	
A-18-P	24	7.4655		Still in test
B-13-NP	4	9.1860	+0.0003	
B-14-NP	12	9.2116	+0.0001	
B-15-NP	24	8.3835		Still in test
B-16-P	4	8.1303	0.0000	
B-17-P	12	8.1769	+0.0001	
B-18-P	24	8.3307		Still in test
C-13-NP	4	8.4668	+0.0003	
C-14-NP	12	8.5117	+0.0004	
C-15-NP	24	8.4145		Still in test
C-16-P	4	7.2249	+0.0001	
C-17-P	12	7.2713	-0.0003	
C-18-P	24	7.5521		Still in test

NOTE: U-bend specimens were not weighed.

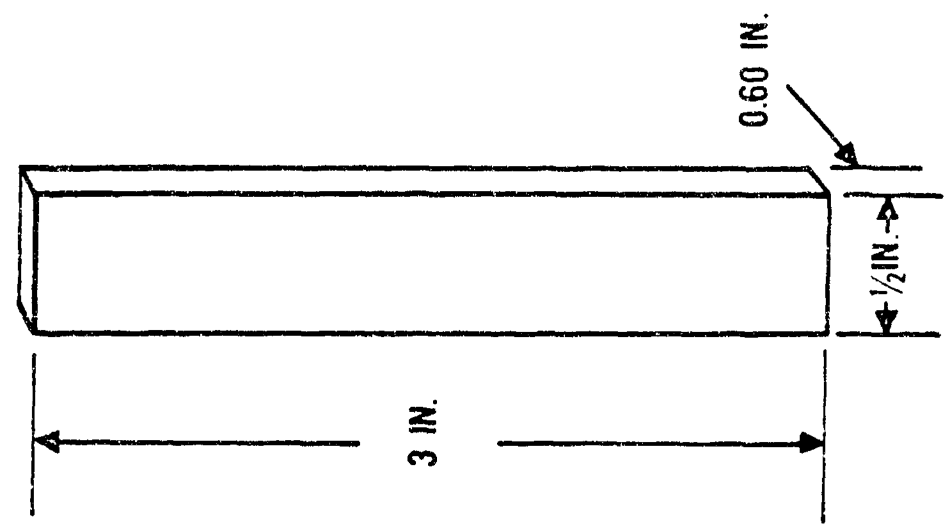
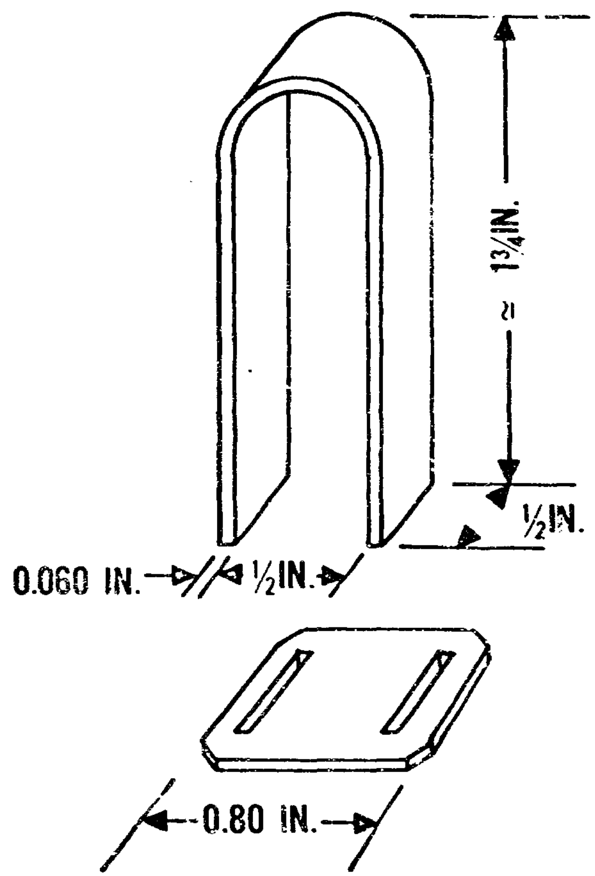


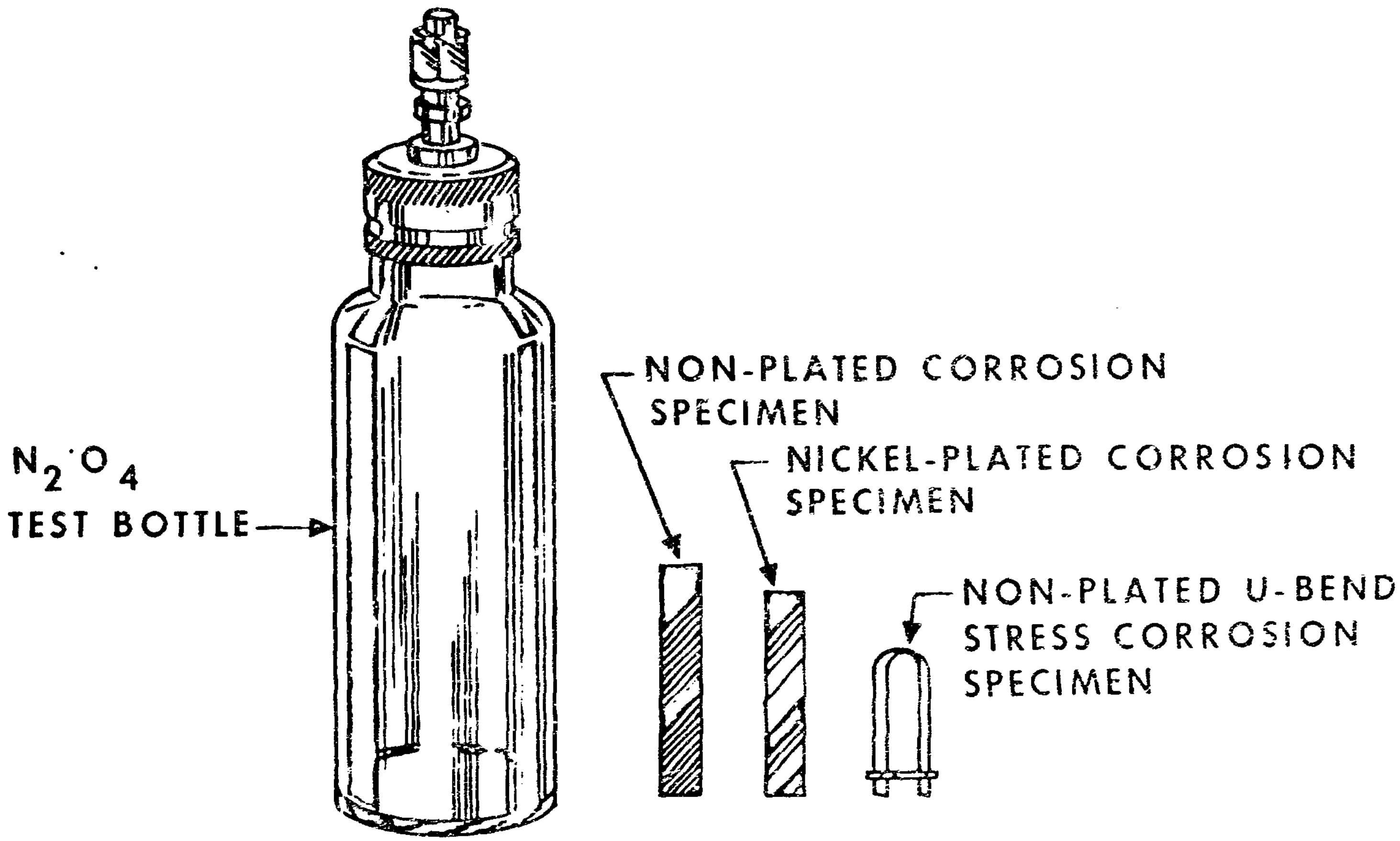
Figure 1- CORROSION COUPON



U-BEND SPECIMEN:
WAS BENT AROUND A 0.50 IN. MANDREL & THEN FITTED TO THE RETAINER STRIP WITHOUT RELAXING THE U-SHAPE

RETAINER STRIP:
MADE OF THE SAME MATERIAL AS THE U-SHAPE SPECIMEN

Figure 2-STRESS CORROSION SPECIMEN



N_2O_4
TEST BOTTLE
NON-PLATED CORROSION
SPECIMEN
NICKEL-PLATED CORROSION
SPECIMEN
NON-PLATED U-BEND
STRESS CORROSION
SPECIMEN

Figure 3

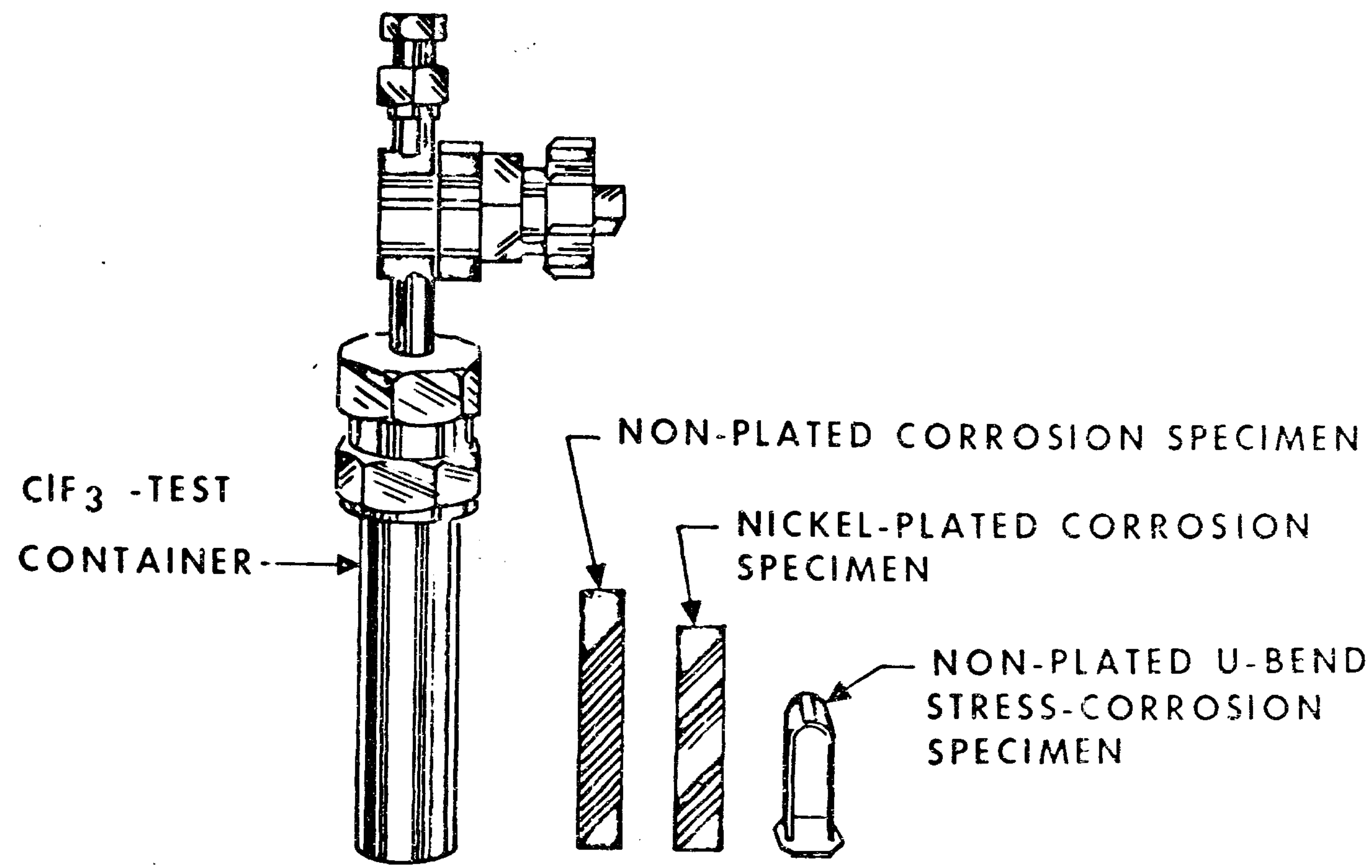
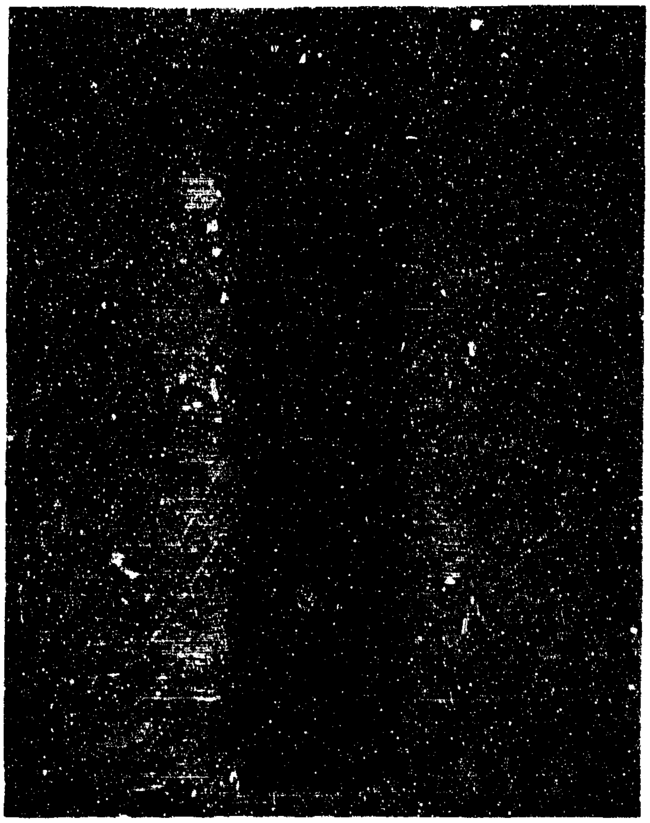

ClF_3 -TEST
CONTAINER
NON-PLATED CORROSION SPECIMEN
NICKEL-PLATED CORROSION SPECIMEN
NON-PLATED U-BEND STRESS-CORROSION SPECIMEN

Figure 4

10X

A-4-P 4 Wks in N_2O_4



2X

A-4-P 4 Wks in N_2O_4

APPENDIX IV

MIL-F-27417 (USAF) MILITARY SPECIFICATION, FITTINGS, ROCKET ENGINE, FLUID CONNECTION

MILITARY SPECIFICATION

FITTINGS, ROCKET ENGINE, FLUID CONNECTION

1. SCOPE

1.1 Scope. This specification establishes the requirements for connection fittings for use in rocket engine fluid systems (6.1).

1.2 Classification. Fittings shall be furnished, as classified by pressure, temperature, and material, in the styles designated by the applicable MS standards as specified herein or other engineering standard drawings approved by the procuring activity (6.1 and 6.2).

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Federal

NN-P-515	Plywood, Container Grade
PPP-B-566	Boxes, Folding, Paperboard
PPP-B-585	Boxes, Wood, Wirebound
PPP-B-591	Boxes, Fiberboard, Wood-Cleated
PPP-B-601	Boxes, Wood, Cleated-Plywood
PPP-B-621	Boxes, Wood, Nailed and Lock Corner
PPP-B-636	Box, Fiberboard
PPP-B-665	Boxes, Paperboard, Metal Stayed (Including Stay Material)
PPP-B-676	Boxes, Set-Up, Paperboard
PPP-C-96	Cans, Metal, 28 Gage and Lighter

Military

MIL-P-116	Preservation, Methods of
MIL-P-130	Paper, Wrapping, Laminated and Creped
MIL-S-5002	Surface Treatments and Metallic Coatings for Metal Surfaces of Weapons Systems

FSC 4730

MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance
MIL-H-6083	Hydraulic Fluid, Petroleum Base, Preservative
MIL-H-6088	Heat Treatment of Aluminum Alloys; Process for (Aircraft Applications)
MIL-S-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter, General Specification For
MIL-L-10547	Liners, Case, and Sheet, Overwrap, Water-Vaporproof, Flexible
MIL-B-13239	Barrier Material, Waterproofed, Flexible All Temperature
MIL-P-17667	Paper, Wrapping, Chemically Neutral (non-corrosive)
MIL-P-27407	Propellant, Pressurizing Agent, Helium
MIL-P-27418	Plating, Soft Nickel (Electrodeposited, Sulfamate Bath)

STANDARDS

Military

MIL-STD-105	Sampling Procesures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MS 27850	Fittings, Installation of Straight Threaded Fluid Connection
MS 27851	Fitting Assembly, Straight Threaded, Fluid Connection, 4000 PSI
MS 27854	Flange, Threaded, Cres., Fluid Connection Fitting, High Pressure
MS 27855	Seal, Cres., Nickel Plated, Fluid Connection Fitting, High Pressure
MS 27856	Fitting Assembly, Straight Threaded, Fluid Connection, Low Pressure
MS 27860	Seal, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27862	Elbow 90°, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27863	Tee, Aluminum, Fluid Connection Fitting, Low Pressure
MS 27866	Elbow 90°, Cres., Fluid Connection Fitting, High Pressure
MS 27867	Tee, Cres., Fluid Connection Fitting, High Pressure

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issue in effect on date of invitation for bids or request for proposal shall apply.

Society of Automotive Engineers

AMS 4083	Aluminum Alloy Tubing, Seamless, Drawn, 1 Mg - 0.6 Si - 0.25 Cu - 0.25 Cr (6061-T6)
AMS 4117	Aluminum Alloy Bars, Rolled, 1 Mg - 0.6 Si - 0.25 Cu - 0.25 Cr (6061-T6)
AMS 4127	Aluminum Alloy Forgings, 1 Mg - 0.6 Si - 0.25 Cu - 0.25 Cr (6061-T6)
AMS 5567	Steel Tubing, Seamless or Welded, Corrosion Resistant, 19 Cr - 10 Ni (SAE 30304), Hydraulic, Solution Treated
AMS 5639	Steel, Corrosion and Heat Resistant, 19 Cr - 9 Ni (SAE 30304)
AMS 5646	Steel, Corrosion and Heat Resistant, 18 Cr - 11 Ni - (Cb + Ta) (SAE 30347)
AMS 5650	Steel, Corrosion and Heat Resistant, 20 Cr - 20 Ni (SAE 30310)
AMS 5651	Steel, Corrosion and Heat Resistant, 23 Cr - 13.5 Ni (SAE 30309)
AMS 5735	Steel, Corrosion and Heat Resistant, 15 Cr - 26 Ni - 1.3 Mo - 2.1 Ti - 0.3 V
AS 478	Identification Marking Methods

(Copies of SAE publications may be obtained from the Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, New York 10017.)

Handbook for Contamination Control of Liquid Rocket Propulsion Systems

(Copies of this handbook may be obtained from Aerospace Industries Association, 610 Shoreham Building, Washington, D. C. 20008.)

3. REQUIREMENTS

3.1 Qualification. The fittings furnished under this specification shall be products which have been tested and have passed the qualification tests specified herein.

3.2 Materials. Fittings shall be fabricated of materials as specified on the applicable standards.

3.2.1 Heat treatment.

3.2.1.1 Aluminum alloy. Mechanical properties and final temper of aluminum fittings shall be as specified in 3.2.1.1.1 and 3.2.1.1.2. All heat treatment shall be done prior to finish machining.

3.2.1.1.1 Nuts, flanges, and forgings. Unless otherwise specified, aluminum material used for nuts and flanges shall conform to AMS 4117 and forgings shall conform to AMS 4127. Final temper shall be T6.

3.2.1.1.2 Seals. Unless otherwise specified, aluminum alloy material used for seals shall conform to AMS 4127, and shall be solution heat treated, overaged, and stabilized prior to finish machining. Overaging shall consist of heating AMS 4127 temper T6 at 425 $^{+10}_{-0}$ degrees Fahrenheit in a vacuum or electric furnace for 10 hours and air cool. The overaged aluminum material shall have the following properties:

(a)	Ultimate tensile strength, psi	39,000 to 43,000
(b)	0.2% yield strength, psi	34,000 to 36,000
(c)	Modulus of elasticity, x 10^6 psi	9.5 to 11
(d)	Hardness, 500 kg Brinell	70 to 76
(e)	Elongation in 2-in. length, percent	15 to 17

3.2.1.2 Corrosion-resistant steel. Mechanical properties of corrosion-resistant steel fittings shall be as specified in 3.2.1.2.1, 3.2.1.2.2, and 3.2.1.2.3.

3.2.1.2.1 Flanges and forgings. Unless otherwise specified, corrosion-resistant material used for flanges and forgings shall conform to AMS 5646 (4.9.6).

3.2.1.2.2 Seals. Unless otherwise specified, corrosion-resistant material used for seals shall be hot-rolled, cold-rolled, or cold-drawn material and shall conform to AMS 5639, AMS 5650, or AMS 5651, and shall be annealed prior to finish machining. The material shall have the following properties:

(a) Hardness - 160 to 180 Brinell
(b) Yield strength - 30,000 to 40,000 psi

3.2.1.2.3 Nuts. Unless otherwise specified, corrosion-resistant material used for nuts shall conform to AMS 5735 and shall be heat treated prior to finish machining. Heat-treated properties shall be certified to satisfy AMS 5735.

3.3 Design and dimensions. The design and dimensions of fittings shall be in accordance with the applicable MS standard.

3.3.1 Passages.

3.3.1.1 Drill offset. On straight fittings where the fluid passage is drilled from each end, the offset between the drilled holes at the meeting point of the drills shall not exceed 0.015 inch. It shall be possible to pass through the fluid passage a ball with a diameter 0.020 inch less than the minimum diameter specified for the passage. This does not mean that the drilled passage may be smaller than that required by the MS standard.

3.3.1.2 Angle fittings. On angle fittings, the cross-sectional area at the junction of the fluid passages shall not be smaller than the cross-sectional area of the smaller passage.

3.3.2 Threads. Unless otherwise specified, straight threads shall be of the unified extra-fine form (UNJEF) and shall conform to MIL-S-8879 except the threads may be cut, ground, or rolled.

3.3.2.1 Rolled threads. The grain flow in the threads shall be continuous and shall follow the general thread contour, with the maximum density at the thread roots as shown in figure 1. Laps and seams whose depth is within the limits of table I are acceptable on the crest, and the nonpressure thread flank above the pitch diameter. Laps and seams are not acceptable on any part of the pressure thread flank, in the thread root, or on the nonpressure thread flank extending from above to below the pitch diameter.

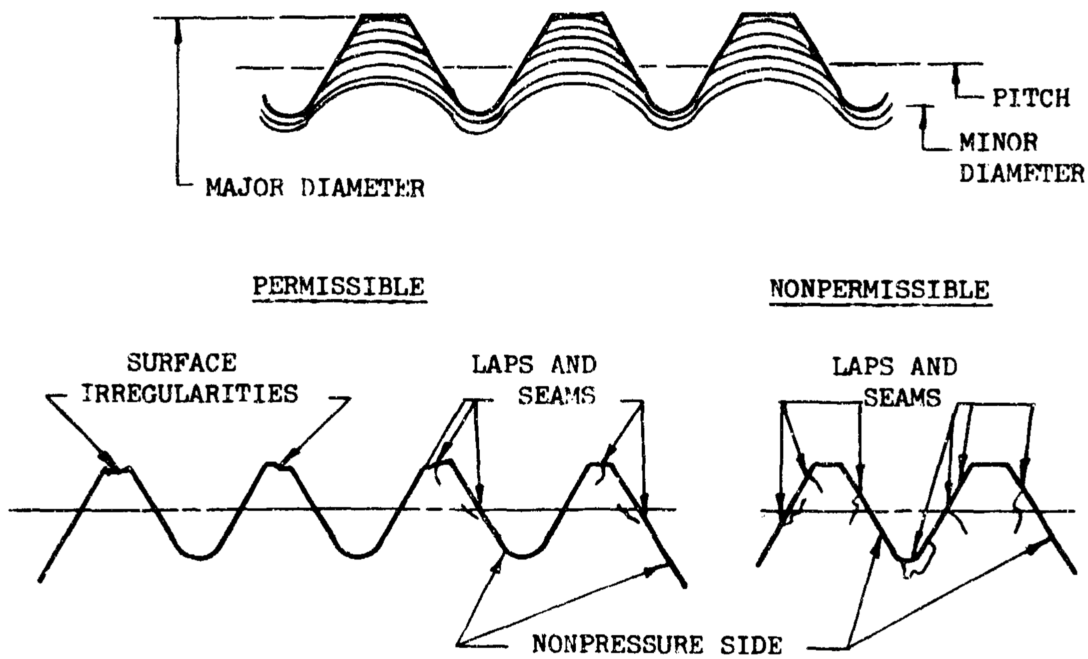


Figure 1. Grain flow and irregularities

TABLE I

Depth of laps, seams, surface irregularities, and discontinuities in rolled threads

Fitting size	Depth (inch) (max)
-2	0.006
-3	.006
-4	.007
-5	.007
-6	.008
-8	.009
-10 through -16	.010

3.4 Finish.

3.4.1 Aluminum-alloy fittings. The surface of aluminum-alloy articles shall be free of pits, powdery coatings, discontinuities such as scratches or breaks and shall be uniform in appearance. Discoloration shall not be cause for rejection.

3.4.2 Corrosion-resistant steel fittings.

3.4.2.1 Corrosion-resistant steel flanges and forgings shall be passivated and capable of meeting the requirements of MIL-S-5002.

3.4.2.2 Corrosion-resistant steel seals shall be surface-treated in accordance with MIL-P-27418.

3.5 Identification of product. All parts shall be identified in accordance with the instructions specified in 3.5.1 and 3.5.2.

3.5.1 MS Standard symbol and manufacturer's trademark. Unless otherwise specified, all fittings and nuts shall be marked with the part number and the manufacturer's identification.

3.5.2 Size, method, and location of marking. Marking shall be accomplished by ink stamp or electrochemical etch on the flanges, forgings, and nuts in the locations indicated on the applicable standards in conformance with AS 478-7A2 or -30.

3.6 Performance. The fittings when welded to tubing, assembled per MS 27850, and tested in accordance with applicable procedures specified in section 4, shall be capable of the performance specified in 3.6.1 through 3.6.8 and in table II.

TABLE II

Performance data

TUBE OD, in.		1/8	1/4	3/8	1/2	3/4	1
Dash size		-2	-4	-6	-8	-12	-16
MS 27851 fitting and stainless steel tube (AMS 5567)	Tube wall thickness, in.	.020	.035	.049	.065	.095	.134
	Working pressure, psi	4,000					
	Working temperature range, °F	-430 to 600					
	Burst pressure at room temp., psi	10,300	14,500	14,200	10,600	10,900	11,000
	Stress level in tube for flexure test, $^{+0}_{-10}$ %, psi	20,000					
MS 27856 fitting and aluminum alloy tube (AMS 4083)	Tube wall thickness, in.	- - -	.022	.028	.035	.035	.049
	Working pressure, psi	1,000	1,000	1,000	1,000	750	750
	Working temperature range, °F	-430 to 200					
	Stress level in tube for flexure test, $^{+0}_{-10}$ %, psi	19,500					

3.6.1 Leakage. Unless otherwise specified, maximum leakage for all conditions except burst pressure shall be measured with a mass spectrometer, and helium per MIL-P-27407 shall be used as a pressurizing agent. A steady leakage rate for a 60-second period exceeding 7×10^{-7} atmospheric cubic centimeters per second shall be considered an excessive leak and cause for rejection. The helium mass spectrometer shall be calibrated with an indicated helium background no greater than 5×10^{-8} atm cc/sec.

3.6.2 Proof pressure. Minimum proof pressure shall be 1-1/2 times the operating pressure shown in table II without exceeding 7×10^{-7} atm cc/sec or permanent deformation (4.9.1).

3.6.3 Burst pressure. All fittings subjected to the burst pressure test shall not fail structurally (4.9.1).

3.6.3.1 Minimum burst pressure for corrosion resistant fittings shall be twice the operating pressure shown in table II when at maximum temperature or three times the operating pressure shown in table II when at room temperature.

3.6.3.2 Minimum burst pressure for aluminum alloy fittings shall be twice the operating pressure shown in table II at maximum temperature.

3.6.4 Thermal shock. At least one of the four samples of each of the assembly material combinations (tube, flanges, nut, and seal) shall withstand six thermal shock cycles without leakage or failure of the fitting parts when tested in accordance with 4.9.2. (Tube failure external to the tube-to-fitting joint prior to six complete cycles is acceptable on any of the other three samples. Leakage of any seal or tube-to-fitting joint prior to six cycles shall constitute failure.)

3.6.5 Flexural strength. At least one of the four samples of each of the assembly material combinations (tube, flanges, nut, and seal) shall withstand 300,000 cycles of flexure, without leakage or failure of the fitting parts when tested in accordance with 4.9.3. (Tube failure external to the fitting joint prior to 300,000 cycles is acceptable on any of the other three samples. Leakage or failure of any flange, nut, or seal on any sample prior to 300,000 cycles shall constitute failure.)

3.6.6 Vibration. At least one of the four samples of each of the assembly material combinations (tube, flanges, nut, and seal) shall withstand 300,000 cycles of vibration without leakage or failure of the fitting parts when tested in accordance with 4.9.4. (Tube failure external to the tube-to-fitting joint prior to 300,000 cycles is acceptable of any of the other three samples. Leakage or failure of any flange, nut, or seal on any sample prior to 300,000 cycles shall constitute failure.)

3.6.7 Repeated assembly. Fittings of all materials shall be capable of the required number of repeated assemblies at both the minimum and maximum torques, without leakage or indication of failure of the nut or flanges (4.9.5). Twenty repeated assemblies shall be the minimum requirement for aluminum alloy and corrosion resistant steel fittings. The seal shall be discarded and a new seal used for each repeated assembly. No deformation in excess of 0.002 inch in the dimensions specified in 4.9.5.1 is permissible and no visual damage to the sealing surface of the seal cavity shall be evident when examined with a 10-power lens.

3.6.7.1 Minimum opening. The internal passages of the flanges and the tubing shall conform to the requirements of 3.3.1.1 and 3.3.1.2 throughout the repeated assembly tests.

3.7 Contamination control. All articles shall be cleaned to level E (Handbook for Contamination Control of Liquid Rocket Propulsion Systems, Aerospace Industries Association) and shall be individually sealed in polyethylene bags.

3.8 Workmanship. Machined surfaces of flanges, nuts, and seals, shall be free from burrs, longitudinal or spiral tool marks. Unless a finer finish is specified on applicable drawings, sealing surfaces on flanges shall be smooth, except that annular tool marks up to 32 microinches arithmetical average (AA) will be acceptable. All other machined surfaces shall not exceed 63 microinches AA. Unmachined surfaces, such as forging surfaces, and barstock flats shall be free of cracks, laps, and seams, and except for forging parting lines, shall not exceed 125 microinches AA.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspections. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specifications where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Lot. A lot shall consist of all parts of a given part number made from the same batch of material of the applicable material specification and processed at the same time. For seals, a lot shall not exceed 500 pieces.

4.2.1 Record maintenance. The supplier shall maintain a record of inspections applied to each lot.

4.2.2 Material certification. Records of chemical composition analysis, mechanical property tests showing conformance to the test requirements specified in MIL-H-6088, shall be made available to the Government inspector for each lot of fittings.

4.3 Classification of tests. Unless otherwise specified, testing of fittings shall be classified as follows:

(a) Qualification test (4.4)
(b) Quality conformance tests (4.5)

4.4 Qualification tests.

4.4.1 Sampling instructions. Qualification test samples shall consist of parts specified in table III, for each size and material for which qualification is desired.

4.4.2 Tests. Qualification tests shall consist of the following requirements and tests, as applicable, and as specified in sections 3 and 4:

(a) Quality conformance tests
(b) Proof pressure (4.9.1)
(c) Burst pressure (4.9.1)
(d) Thermal shock (4.9.2)
(e) Flexure (4.9.3)
(f) Vibration (4.9.4)
(g) Repeated assembly (4.9.5)

4.5 Quality conformance test.

4.5.1 Sampling.

4.5.1.1 Nondestructive tests. Unless otherwise specified, sampling for material, threads, finish, dimensions, marking, surface defects, and workmanship shall be at random in accordance with MIL-STD-105 at an acceptance quality level (AQL) of 2.5 percent.

4.5.1.2 Destructive tests. Sampling for tests specified in (d) through (j) of 4.5.2 shall be performed in accordance with MIL-STD-105, inspection level S-1, acceptance number zero.

4.5.2 Tests. Each individual lot of forgings, flanges, nuts, and seals shall conform to the following requirements and be subjected to the following tests, as applicable, and as specified in sections 3 and 4:

(a) Examination of product (4.8.1)
(b) Chemical composition (3.2 and 4.2.2)
(c) Physical properties (3.2.1.2.1 and 4.2.2)
(d) Metallurgical properties (seal only) (3.2.1.2.2 and MIL-P-27418)

TABLE III

Qualification test samples

Quantity	Part No.	Material	Applicable test
4 each 4 each	MS 27866 MS 27867	1/	Proof pressure (3.6.2 and 4.9.1)
4 each 4 each	MS 27862 MS 27863	2/	Proof pressure (3.6.2 and 4.9.1)
4 each 4 each	MS 27866 MS 27867	1/, 3/	Burst pressure (3.6.3 and 4.9.1)
4 each 4 each	MS 27862 MS 27863	2/, 3/	Burst pressure (3.6.3 and 4.9.1)
4 each 4 each	MS 27851 MS 27856	1/ 2/	Thermal shock (3.6.4 and 4.9.2)
4 each 4 each	MS 27851 MS 27856	1/ 2/	Flexure (3.6.5 and 4.9.3)
4 each 4 each	MS 27851 MS 27856	1/ 2/	Vibration (3.6.6 and 4.9.4)
2 each 2 each	MS 27851 MS 27856	1/ 2/	Repeated assembly (3.6.7 and 4.9.5)
2 each 2 each	MS 27855 MS 27860	1/ 2/	Hardness (seal only) (4.9.6.2)
4 each	MS 27854	1/	Grain flow (3.3.2.1 and 4.9.7)
2 each	MS 27855	1/, 5/	Grain structure (seal only) (4.9.8)
2 each 2 each	MS 27851 MS 27856	1/, 5/ 2/	Seal interface (4.9.9)
2 each	MS 27855	1/, 5/	Adherence (4.9.10)
4/	4/	4/	Quality conformance tests

1/ Corrosion-resistant steel fittings only.
2/ Aluminum-alloy fittings only
3/ This test specimen may be obtained from the proof pressure test (4.9.1) after its completion.
4/ All samples subjected to qualification tests shall previously have been subjected to the specified quality conformance tests (a), (b), (c), (e), of 4.5.
5/ This test specimen may be obtained from the seals hardness test (4.9.6.2) after its completion.

(e) Hardness (3.2.1.2 and 4.9.6)
(f) Grain flow (3.3.2.1 and 4.9.7)
(g) Grain structure (seal only) (4.9.8)
(h) Seal interface (4.9.9)
(i) Burst pressure (4.9.1)
(j) Adherence (seal only) (4.9.10 and MIL-P-27418)

4.6 Rejection and retest. Rejected lots shall be resubmitted for retest and acceptance in accordance with MIL-STD-105. Parts subjected to non-destructive tests and failing to conform to the requirements of these tests shall be rejected. Parts subjected to destructive tests shall be discarded.

4.7 Test conditions.

4.7.1 Thread lubricant. Thread lubricant shall be applied as specified in MS 27850.

4.7.2 Test fluid. The test fluid shall be helium gas conforming to MIL-P-27407 for all tests except the burst test for which hydraulic fluid conforming to MIL-H-5606 or MIL-H-6083 may be used.

4.7.3 Assembly torques. Fittings shall be tightened with a torque wrench calibrated to be accurate to within ±5 percent. Minimum and maximum assembly torques shall be those designated in MS 27850.

4.7.4 Tube material and working pressure. Aluminum-alloy fittings shall be tested with aluminum-alloy tubing as specified in AMS 4083. Corrosion-resistant steel fittings shall be tested with annealed stainless steel tubing as specified in AMS 5567. Working pressure shall be as specified in table II.

4.7.5 Proof pressure. Unless otherwise specified proof pressure shall be 1-1/2 times the working pressure specified in table II.

4.7.6 Burst pressure. Unless otherwise specified, burst pressure shall be twice the working pressure specified in table II.

4.8 Examinations.

4.8.1 Each lot of fittings shall be examined to determine conformance with this specification and the applicable standards with respect to material, dimensions, threads, wall thickness, surface defects, finish, marking, and workmanship.

4.8.2 Preparation for delivery. The preservation, packaging, and marking shall be examined for conformance to section 5.

4.8.2.1 Sampling. Sampling shall be performed in accordance with MIL-STD-105, inspection level S-1, acceptance number zero. Classification of defects shall be as shown in table IV.

TABLE IV

Classification of defects for preparation for delivery

Item	Defects
Exterior and interior markings	Missing, incorrect, incomplete, illegible, of improper size, location, sequence, or method of application
Materials	Any nonconforming component; component missing, damaged, or otherwise defective
Workmanship	Inadequate assembly of components
Exterior and interior weight or content	Number per container is more or less than stipulated; gross or net weight exceeds the requirement

4.9 Test methods.

4.9.1 Proof and burst pressure. For qualification, elbows and tees shall be used in this test. Fittings shall be assembled so that at least 8 inches of free tubing extends between the two restraints of the test fixture. One half of the samples shall be assembled at minimum torque and the other half shall be assembled at maximum torque. The fittings shall be raised to the proof pressure for 5 minutes and shall be heated to the maximum temperature listed in table II. Leakage shall be continuously monitored with a mass spectrometer. For the burst test the fitting shall be at room temperature for the corrosion resistant steel fittings and maximum temperature for aluminum alloy fittings. Continuous monitoring of leakage need not be performed if hydraulic fluid is used. Pressure shall be raised at a rate of 20,000 $\pm$ 5.000 psi per minute until burst or leakage occurs, as indicated by changes in gage pressure.

4.9.2 Thermal shock. For qualification tests only straight tube fittings shall be used. One half of the samples shall be assembled at minimum torque and the other half at maximum torque. A bellows-type expansion chamber evacuated to a mass spectrometer shall enclose the fitting. The net axial force exerted on the tube assembly by thermal expansion or contraction of the bellows expansion chamber shall not exceed 50 pounds.

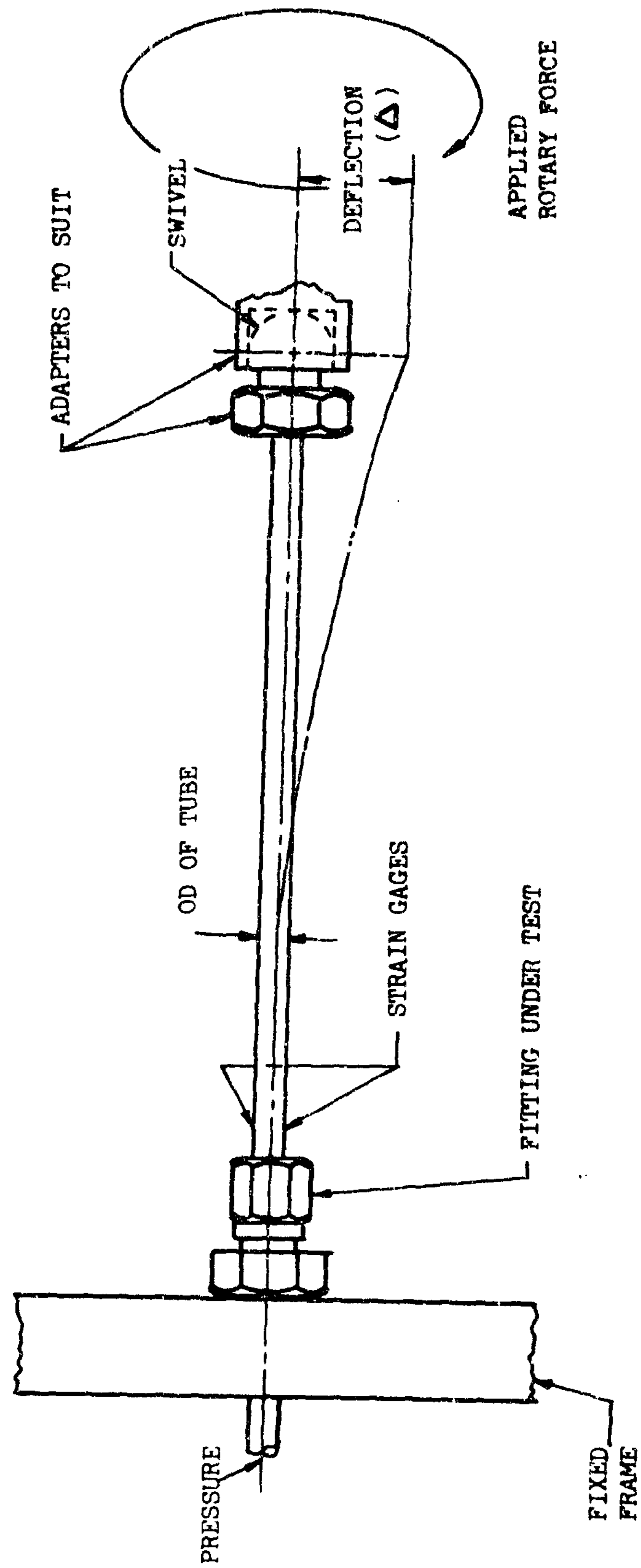


Figure 2. Cantilever-beam method

The fitting assembly shall be heated to the maximum temperature specified in table II, and pressurized for 5 minutes at the proof pressure. If leakage does not exceed 7×10^{-7} atm cc/sec, the pressure shall be reduced to the working pressure and the fitting shall be cooled to room temperature. Thereafter six thermal shock cycles, as specified in table V, shall be performed. The pressure shall be held constant throughout the test at all temperatures. Upon completion of the six thermal shock cycles, the pressure shall be raised to proof pressure for 5 minutes.

TABLE V

Sequence of thermal shocks

	Cycle number					
	1	2	3	4	5	6
Initial temperature	RT	RT	RT	1/	1/	1/
Intermediate temperature	-320	-320	-320	RT	RT	RT
Cooling period, min.	5-8	5-8	5-8	5-12	5-12	5-12
Final temperature	RT	RT	RT	1/	1/	1/
Heating period, min.	5-8	5-8	5-8	5-12	5-12	5-12

1/ 600°F for corrosion-resistant steel fittings; 200°F for aluminum-alloy fittings.

4.9.3 Flexure. The flexure test may be conducted in one of several ways. The preferred method is shown in figure 2. Any method may be used, provided that the stress level indicated in table II is imposed and measured as specified, the fitting is heated to the maximum temperature specified in table II, and leakage is continuously measured with a mass spectrometer. The stress level measured shall be the axial tensile stress. Measurement of the stress shall be obtained by placing two strain gages, 180 degrees apart, on the periphery of the tube in the plane of maximum stress. The centers of the strain gage shall be placed within 3/16 ± 1/64 inch from the back of the nut flange as indicated in figure 2. During the test, a constant pressure equal to the working pressure noted in table II shall be imposed. Frequency of flexing may be any rate from 30 to 60 cycles per second. One half of the specimens shall be assembled with maximum torque and the remaining half shall be assembled with minimum torque. Duration of the test shall be 300,000 cycles or until prior failure or leakage occurs. Upon completion of the six thermal shock cycles, the pressure shall be raised to proof pressure for 5 minutes.

4.9.3.1 Cantilever-beam method. Figure 2 shows the cantilever-beam method applied to a tube union fitting, wherein the flexural requirements are obtained by imposing a concentrated load on the free-swiveling end of the tube assembly. The opposite end (test fitting) is rigidly supported in

a fixture. The motion of the free end shall be rotary and the eccentric shall be adjustable to obtain the desired stress level in the tube. Offset distance (Δ) shall be determined by actual stress measurement after the tubing assembly is pressurized at room temperature.

4.9.4 Vibration. The vibration test shall be conducted in one of several ways. One method is shown in figure 3. Any method may be used, provided that the stress level indicated in table II is imposed and measured as specified, and the fitting is heated to the maximum temperature specified in table II. Leakage may be monitored by variations in pressure gage readings during the test. A mass spectrometer leak check shall be performed upon conclusion of the test under static conditions and proof pressure if failure does not occur during the test. The stress level measured shall be the axial tensile stress. Measurement of the stress shall be obtained by placing two strain gages, 180 degrees apart, in the periphery of the tube in the plane of maximum stress. The center of the strain gage shall be placed within 3/16 ± 1/64 inch from the back of the nut flange as indicated in figure 3. During the test, a constant pressure equal to the working pressure noted in table II shall be imposed. Frequency of flexing shall be at the lowest resonant frequency of the fitting and tube assembly depending on the method selected. The specimens shall be assembled with minimum tightening torques only. Duration of the test shall be 300,000 cycles or until prior failure or leakage occurs. Upon completion of the six thermal shock cycles, the pressure shall be raised to proof pressure for 5 minutes.

4.9.4.1 Indeterminate-beam method. Figure 3 shows one method, wherein the test arrangement is essentially an indeterminate beam, with concentrated load at the center, mounted on a "shaker". Both supports shall provide rigid clamping. Amplitude shall be determined statically, by measuring the deflection at the center of the span caused by premeasured weights, required to generate the required stress actually measured with strain gages after the tubing assembly is pressurized at room temperature.

4.9.5 Repeated assembly.

4.9.5.1 Minimum tightening. The tube and fitting assembly shall be assembled and disassembled the number of times specified in 3.6.7 using the torque values specified in MS 27850. Torques shall be recorded and the dimensions indicated in figure 4 shall be measured and recorded after each disassembly. Each tightening operation shall first include the assembly of, and then the complete removal of the seal from the flange seal cavities in the manner specified in MS 27850. A new seal shall be used for each assembly. After each fifth tightening operation, the assembly shall be subjected to the proof pressure for 5 minutes. The fitting shall then be examined for structural damage with a 10-power lens (3.6.7). After the final tightening operation, the assembly shall be subjected to the burst pressure test (4.9.1).

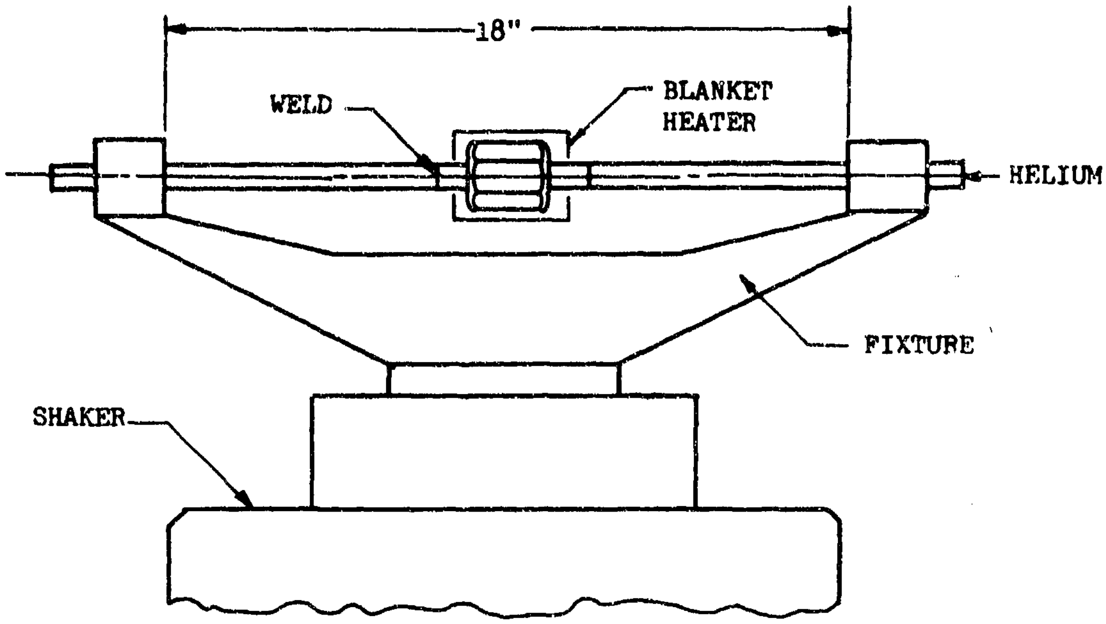


Figure 3. Indeterminate-beam method

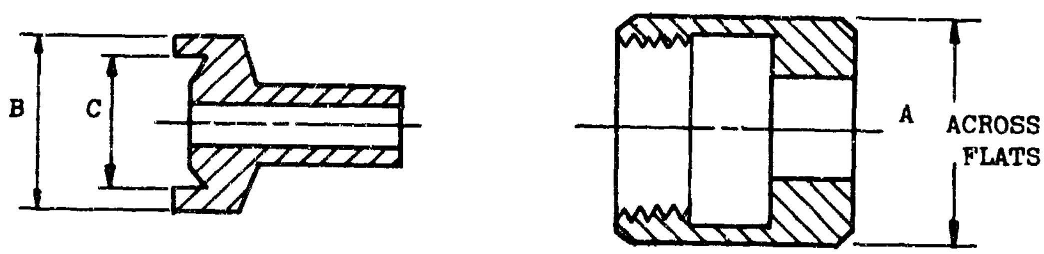


Figure 4. Dimensions to be measured during repeated assembly test

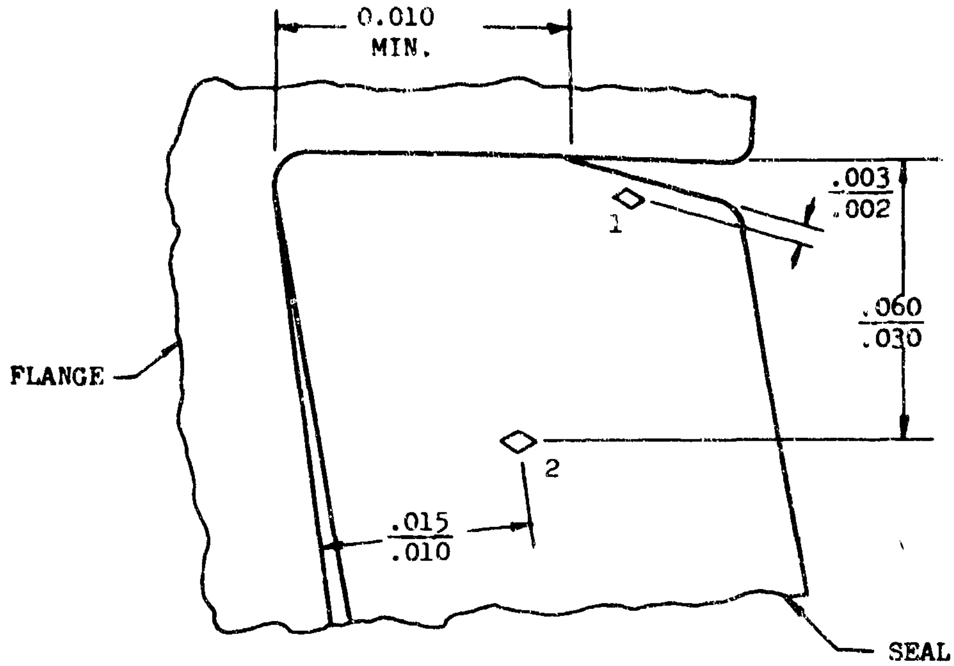


Figure 5. Location of hardness readings for aluminum-alloy seals

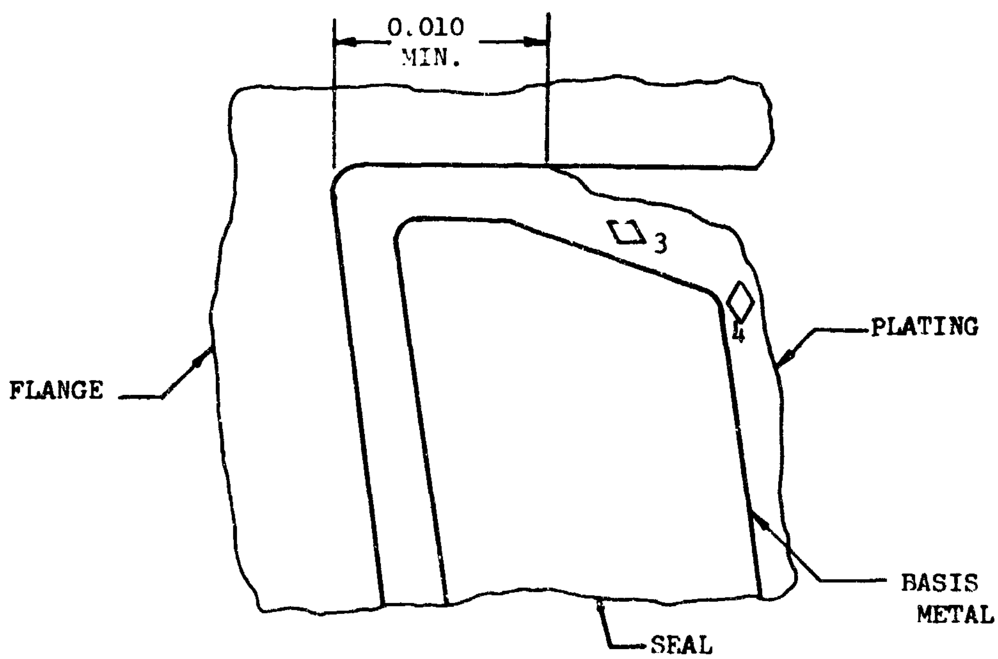


Figure 6. Location of hardness readings for plated corrosion-resistant steel seals

4.9.5.2 Maximum tightening. The test specified in 4.9.5.1 shall be performed using new assemblies, with the maximum torques specified in MS 27850.

4.9.6 Hardness.

4.9.6.1 Fittings. Hardness readings shall be taken on a smooth flat surface of any unthreaded portion of flanges, forgings, or nuts except in the sealing surfaces.

4.9.6.2 Seals. For qualification two fittings shall be assembled with the minimum torque specified in MS 27850. Microsections shall be prepared along the longitudinal axis after which the fitting shall be encased in an appropriate matrix. Knoop or equivalent hardness readings shall be taken at the locations indicated in figures 5 and 6. The hardness of the seals shall conform to those specified in table VI.

TABLE VI

Hardness at specified locations

Material	Figure	Location	Maximum Knoop hardness
Aluminum	5	1 2	79 with 500-gram load
Stainless steel	6	3 4	150 with 500-gram load

4.9.7 Grain flow in threads. Grain flow in threads shall be determined by macroexamination. Specimens shall be taken from the finished part by sectioning on a longitudinal plane across the threaded area. The specimen shall be etched for sufficient time to reveal the macrostructure adequacy.

4.9.8 Grain structure. The microsections prepared in 4.9.6.2 for hardness test of corrosion-resistant seals shall be examined at a 100 magnification for grain structure of the plating. There shall be no crevices or incipient crevices or cracks along the outer surface of the plating at the grain boundary.

4.9.9 Seal interface. The microsections prepared in 4.9.6.2 shall be examined and the length of the seal interface shall be measured and recorded. The length of the seal interface shall be at least 0.01 inch long as indicated in figures 5 and 6 and the restraining flanges shall be free of distortion, gross deformation, or indentation.

4.9.10 Adherence. The microsections prepared in 4.9.6.2 for corrosion-resistant seals shall be examined at a 100 magnification for adherence between the basis metal and the plating. There shall be no evidence of nonadherence or incipient separation at any point along the entire interface between the basis metal and the plating.

4.9.11 Surface finish. All nonplated seals shall have a smooth, even, uniform surface finish on the sealing surfaces not exceeding 32 microinches AA as measured by a Talysurf recorder or equivalent. Plated seals shall be smooth, even, and uniform without the presence of pimples, blisters, beads, nodules, flaking, or peeling. Thickness of the plating at the seal interface prior to assembly shall be 0.003 inch $\pm$ 0.0005. The thickness on all non-sealing surfaces shall conform with MIL-P-27418. Slight discoloration due to plating and post-annealing process is acceptable. Marks caused by the electrical contacts are allowed if located on noncritical surfaces as indicated in the applicable standards and if flaking, peeling, or contamination will not result after assembly (3.7).

5. PREPARATION FOR DELIVERY

5.1 Preservation and cleaning.

5.1.1 Preservation. No preservative compound shall be applied to the fittings.

5.1.2 Cleaning. Before packaging, all parts shall be free from grease, oil, dirt, or any other foreign matter.

5.2 Packaging. Packaging shall be Level A or Level C, as specified (6.2).

5.2.1 Level A.

5.2.1.1 Fitting unit containers. All fittings except nuts and seals shall be unit packaged in accordance with Method IC-1 of MIL-P-116, except as modified herein. The quantity per unit package shall be one. After bagging, fittings greater than 3-1/2 inches in any dimension shall be individually overpacked in cartons conforming to PPP-B-636, PPP-B-566, PPP-B-676, or PPP-B-665. If it is necessary to wrap the fittings prior to inserting in bags to prevent damage, fittings shall be wrapped with barrier materials conforming to MIL-P-17667 or MIL-P-130.

5.2.1.2 Alternate unit protection. Five fittings of one type and size, up to and including 1-1/2 inches in any dimension, may be packaged in perforated tear-apart cartons in accordance with Method III of MIL-P-116. Each carton shall have interior separations capable of supporting and

separating each individual fitting in such manner as to prevent movement or contact of the fittings with each other. All surfaces of the carton coming in direct contact with the item shall be of a type that will not induce corrosion and be capable of withstanding slight abrasion. Fittings over 1-1/2 inches shall be packaged individually in accordance with 5.2.1.1.

5.2.1.3 Nuts and seals, unit containers. Nuts and seals of one type and size shall be unit packaged in accordance with Method IC-1 of MIL-P-116, or in friction-top hermetically sealed cans conforming to PPP-C-96. The quantity per unit container shall be as specified in table VII.

TABLE VII

Quantity per unit container

Size (inches)	Number
1/8 to 1/2	100
5/8 to 1-1/4	25
1-1/2 to 3	5
over 3	1

5.2.1.4 Fitting intermediate containers. Unit packages shall be packaged in intermediate containers conforming to PPP-B-636, PPP-B-566, PPP-B-676, or PPP-B-665. The quantity of unit packages per intermediate container shall be as specified in table VIII, except that intermediate containers are not required for fittings individually packed in unit cartons in accordance with 5.2.1.1.

TABLE VIII

Quantity of packages

Size (inches)	Quantity of unit packages per intermediate container	Quantity of tear-apart cartons per intermediate container
1/8 through 1/4	100	20
5/16 through 1/2	25	10
5/8 through 1	10	5
1-1/4 through 3-1/2	5	1

5.2.2 Level C. All forgings, fittings, nuts, and seals shall be packaged as necessary to prevent damage or deterioration during shipment.

5.3 Packing. Packing shall be Level A, B, or C, as specified (6.2).

5.3.1 Level A. Fittings, packaged as specified herein, shall be packed in overseas-type shipping containers conforming to PPP-B-601, PPP-B-621, PPP-B-585, PPP-B-591, or PPP-B-636. Shipping containers, insofar as possible, shall contain the same number of articles, shall be uniform in shape and size and snugly packed, shall be of minimum cube and tare consistent with the protection required, and shall contain identical quantities. The gross weight of the fully packed exterior shipping container shall not exceed 200 pounds except fiberboard containers, which shall not exceed the weight limitations of the applicable container specification. Plywood, when used, shall be Type I or II, class 2, of NN-P-515. Strapping and closures shall be in accordance with the appendix to the applicable container specification. Containers conforming to PPP-B-585 or PPP-B-621 shall be provided with a case liner conforming to MIL-L-10547, except the material shall conform to MIL-B-13239, and shall be sealed in accordance with the appendix to MIL-L-10547. No case liner is required when material conforming to Class 2 of PPP-B-636 is used as an intermediate container.

5.3.2 Level B. Fittings packaged as specified herein shall be packed in domestic-type shipping containers conforming to PPP-B-636, PPP-B-585, PPP-B-591, PPP-B-601, or PPP-B-621. Closures shall be in accordance with the appendix to the applicable container specification. Fiberboard, when used, shall have a minimum Mullen test of not less than 275 pounds. The gross weight of the shipping container, when packed for shipment, shall not exceed 200 pounds; fiberboard containers shall not exceed the weight limitations specified in applicable container specification.

5.3.3 Level C. Packages which require overpacking for acceptance by the carrier shall be packed in commercial exterior shipping containers in a manner that will insure safe transportation at the lowest rate to the point of delivery. Containers shall be in accordance with Uniform Freight Classification Rules or regulations of other common carriers as applicable to the mode of transportation.

5.4 Marking of shipments. If tear-apart containers are used, each section of the unit container shall be marked with the part number of the item. In addition to any other special marking required by the contract or order, marking for shipment shall be in accordance with MIL-STD-129.

6. NOTES

6.1 Intended use. Fittings MS 27850 through MS 27868 covered by this specification are intended for use in rocket engine fluid systems (1.1).

6.1.1 Since fittings of several materials are described in this specification, and various tube-fitting material combinations can be selected for various systems, qualification approval of the product specified herein approves the product only for use in such manner as defined in the qualification tests.

6.1.2 These fittings were designed by a computer program which may be used for optimizing fitting designs for other criteria. Contact the procuring activity for further information.

6.2 Ordering data. Procurement documents should specify:

(a) Title, number, and date of this specification
(b) Part no. required (1.2 and 3.4)
(c) Applicable levels of preservation, packaging, and packing (5.2 and 5.3).

6.3 Qualification. With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved by the Air Force Rocket Propulsion Laboratory, whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible is the Air Force Rocket Propulsion Laboratory. Information pertaining to qualification of products may be obtained from the Air Force Rocket Propulsion Laboratory.

Custodians:

Air Force - 12

Preparing Activity:

Air Force - 12

Review activities:

Air Force - 11, 14, 19, 69, 85

Civilian Agencies Interest:

NAS

Reviewer/user information is current as of the date of this document. For further coordination of changes to this document, draft circulation should be based on the information in the current DoD Index of Specifications and Standards.

SPECIFICATION ANALYSIS SHEET	Form Approved Budget Bureau No. 119-R004

INSTRUCTIONS

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity *(as indicated on reverse hereof)*.

SPECIFICATION

MIL-F-27417 Fittings, Rocket Engine, Fluid Connection

ORGANIZATION *(of submitter)*	CITY AND STATE

CONTRACT NO.	QUANTITY OF ITEMS PROCURED	DOLLAR AMOUNT
		$

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

A. GIVE PARAGRAPH NUMBER AND WORDING.

B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES.

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

☐ YES ☐ NO IF "YES", IN WHAT WAY?

4. REMARKS *(Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity)*

SUBMITTED BY *(Printed or typed name and activity)*	DATE

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Air Force Rocket Propulsion Laboratory (RPPS)
Edwards, California 93523

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Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Battelle Memorial Institute, Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

"Seal Design Modification for AFRPL Stainless Steel Threaded Connectors"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report, August 1, 1969, December 1, 1970

5. AUTHOR(S) (Last name, first name, initial)

Baum, J. V., Ghadiali, N. D., Trainer, T. M.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1970	82	-

8a. CONTRACT OR GRANT NO. F04611-69-C-0028 NFW b. PROJECT NO. 3058 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) Program Element No. 6.23.02F, Exhibit A-1

10. AVAILABILITY/LIMITATION NOTICES

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of AFRPL (RPOR/STINFO), Edwards, California 93523

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Systems Command Rocket Propulsion Laboratory Edwards Air Force Base, California 93523

13. ABSTRACT

An analysis of excessive connector helium leakage indicated that the radial sealing forces in the 1/2-, 3/4-, and 1-inch AFRPL stainless steel threaded connectors were too low to overcome manufacturing variations in the metal-plated seals. A program was undertaken to investigate three candidate materials for increasing the radial sealing forces in these three connector sizes, and to reassess the adequacy of the specification by which the seals were plated, i.e., MIL-P-27418 (USAF), Military Specification, Plating, Soft Nickel. Selected material properties, including yield strength and corrosion resistance, were investigated for cold-worked Type 304 stainless steel, Armco 21-6-9, and iron-base superalloy 19-9 DL. Preliminary tests were conducted for seal designs for each material, and verification tests were conducted for seal designs for Type 304 and Armco 21-6-9 stainless steel. Plating companies were contacted concerning the adequacy of MIL-P-27418 (USAF). It was concluded that the plating specification is satisfactory if the inspection is done with a 5-power glass. It was also concluded that modified seal designs utilizing cold-worked Type 304 stainless steel will achieve the desired performance requirements in the 1/2-, 3/4-, and 1-inch connectors and that the same seal designs utilizing annealed Armco 21-6-9 will probably achieve the desired performance requirements. It was recommended that the necessary changes be incorporated in the plating and connector specifications.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fittings						
Threaded connectors						
Bobbin seals						
304 stainless steel						
21-6-9 stainless steel						
19-9 DL superalloy						
Thermal gradients						
Vibration						
Misalignment						
Pressure impulse						
Stress-reversal bending						
Corrosion						
Nickel plating						

Security Classification